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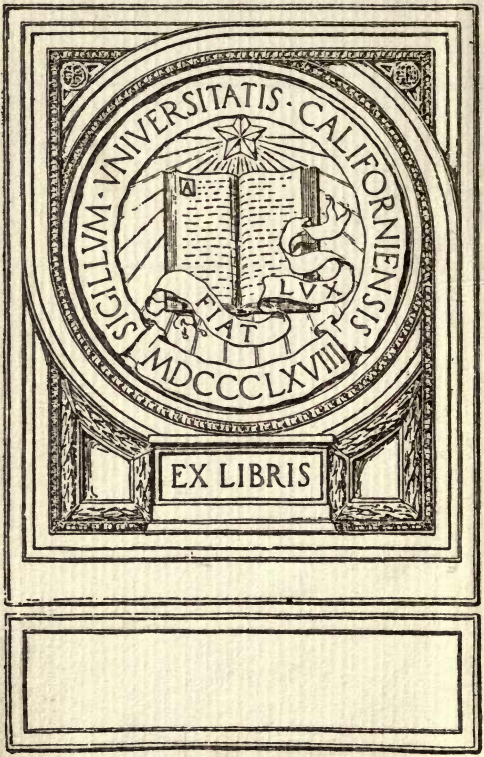
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THE CHEMISTRY, PROPERTIES AND TESTS OF PRECIOUS STONES.

BY

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London
E. & F. N. SPON, LIMITED, 57 HAYMARKET
New York
SPON & CHAMBERLAIN, 123 LIBERTY STREET

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PREFACE

SOME little time ago certain London diamond merchants and wholesale dealers in precious stones made the suggestion to me to write a work on this section of mineralogy, as there did not appear to be any giving exactly the information most needed.

Finding there was a call for such a book I have written the present volume in order to meet this want, and I trust that this handbook will prove useful, not only to the expert and to those requiring certain technical information, but also to the general public, whose interest in this entrancing subject may be simply that of pleasure in the purchase, possession, or collection of precious stones, or even in the mere examination of them through the plate-glass of a jeweller's window.

JOHN MASTIN.

TOTLEY BROOK,
NEAR SHEFFIELD.
June 1911.

THE

CHEMISTRY, PROPERTIES AND TESTS OF PRECIOUS STONES

CHAPTER I.

INTRODUCTORY.

WHAT constitutes a precious stone is the question which, at the onset, rises in the mind, and this question, simple as it seems, is one by no means easy to answer, since what may be considered precious at one time, may cease to be so at another.

There are, however, certain minerals which possess distinctive features in their qualities of hardness, colour, transparency, refractability or double refractability to light-beams, which qualities place them in an entirely different class to the minerals of a metallic nature. These particular and non-metallic minerals, therefore, because of their comparative rarity, rise pre-eminently above other minerals, and become actually "precious."

This is, at the same time, but a comparative term, for it will readily be understood that in the case of a sudden flooding of the market with one class of stone, even if it

should be one hitherto rare and precious, there would be an equally sudden drop in the intrinsic value of the jewel to such an extent as perhaps to wipe it out of the category of precious stones. For instance, rubies were discovered long before diamonds; then when diamonds were found these were considered much more valuable till their abundance made them common, and they became of little account. Rubies again asserted their position as chief of all precious stones in value, and in many biblical references rubies are quoted as being the symbol of the very acme of wealth, such as in Proverbs, chapter iii., verses 13 and 15, where there are the passages, "happy is the man that findeth wisdom . . . . she is more precious than rubies"—and this, notwithstanding the enormous quantity of them at that time obtained from the ruby mines of Ophir and Nubia, which were then the chief sources of wealth.

It will also be remembered that Josephus relates how, at the fall of Jerusalem, the spoil of gold was so great that Syria was inundated with it, and the value of gold there quickly dropped to one-half; other historians, also, speaking of this time, record such a glut of gold, silver, and jewels in Syria, as made them of little value, which state continued for some considerable period, till the untold wealth became ruthlessly and wastefully scattered, when the normal values slowly reasserted themselves.

Amongst so many varieties of these precious minerals, it cannot be otherwise than that there should be important differences in their various characteristics, though for a stone to have the slightest claim to be classed as "precious" it must conform to several at least of the following re-

quirements :—It must withstand the action of light without deterioration of its beauty, lustre, or substance, and it must be of sufficient hardness to retain its form, purity and lustre under the actions of warmth, reasonable wear, and the dust which falls upon it during use ; it must not be subject to chemical change, decomposition, disintegration, or other alteration of its substance under exposure to atmospheric air ; otherwise it is useless for all practical purposes of adornment or ornamentation.

There are certain other characteristics of these curious minerals which may be classified briefly, thus :—Some stones owe their beauty to a wonderful play of colour or fire, due to the action of light, quite apart from the colour of the stone itself, and of this series the opal may be taken as a type. In others, this splendid play of colour is altogether absent, the colour being associated with the stone itself, in its substance, the charm lying entirely in the superb transparency, the ruby being taken as an example of this class of stone. Others, again, have not only colour, but transparency and lustre, as in the coloured diamonds, whilst the commoner well-known diamonds are extremely rich in transparency and lustre, the play of light alone showing a considerable amount of brilliancy and beauty of colour, though the stone itself is clear. Still others are opaque, or semi-opaque, or practically free from play of light and from lustre, owing their value and beauty entirely to their richness of colour.

In all cases the value of the stone cannot be appreciated fully till the gem is separated from its matrix and polished, and in some cases, such as in that of the diamond, cut in variously shaped facets, on and amongst

which the light rays have power to play; other stones, such as the opal, turquoise and the like, are cut or ground in flat, dome-shaped, or other form, and then merely polished. It frequently happens that only a small portion of even a large stone is of supreme value or purity, the cutter often retaining as his perquisite the smaller pieces and waste. These, if too small for setting, are ground into powder and used to cut and polish other stones.

Broadly speaking, the greatest claim which a stone can possess in order to be classed as precious is its rarity. To this may be added public opinion, which is led for better or worse by the fashion of the moment. For if the comparatively common amethyst should chance to be made extraordinarily conspicuous by some society leader, it would at once step from its humbler position as semi-precious, and rise to the nobler classification of a truly precious stone, by reason of the demand created for it, which would, in all probability, absorb the available stock to rarity; and this despite the more entrancing beauty of the now rarer stones.

The study of this section of mineralogy is one of intense interest, and by understanding the nature, environment, chemical composition and the properties of the stones, possibility of fraud is altogether precluded, and there is induced in the mind—even of those with whom the study of precious stones has no part commercially—an intelligent interest in the sight or association of what might otherwise excite no more than a mere glance of admiration or curiosity. There is scarcely any form of matter, be it liquid, solid, or gaseous, but has

yielded or is now yielding up its secrets with more or less freedom to the scientist. By his method of synthesis (which is the scientific name for putting substances together in order to form new compounds out of their union) or of analysis (the decomposing of bodies so as to divide or separate them into substances of less complexity), particularly the latter, he slowly and surely breaks down the substances undergoing examination into their various constituents, reducing these still further till no more reduction is possible, and he arrives at their elements. From their behaviour during the many and varied processes through which they have passed he finds out, with unerring accuracy, the exact proportions of their composition, and, in many cases, the cause of their origin.

It may be thought that, knowing all this, it is strange that man does not himself manufacture these rare gems, such as the diamond, but so far he has only succeeded in making a few of microscopic size, altogether useless except as scientific curiosities. The manner in which these minute gems and spurious stones are manufactured, and the methods by which they may readily be distinguished from real, will be dealt with in due course.

The natural stones represent the slow chemical action of water, decay, and association with, or near, other chemical substances or elements, combined with the action of millions of years of time, and the unceasing enormous pressure during that time of thousands, perhaps millions, of tons of earth, rock, and the like, subjected, for a certain portion at least of that period, to extremes of heat or cold, all of which determine the

nature of the gem. So that only in the earth itself, under strictly natural conditions, can these rare substances be found at all in any workable size; therefore they must be sought after assiduously, with more or less speculative risk.

CHAPTER II.

THE ORIGIN OF PRECIOUS STONES.

THOUGH the origin, formation, composition, characteristics and tests of each stone will be examined in detail when dealing with the stones seriatim, it is necessary to enquire into those particulars of origin which are common to all, in order thoroughly to understand why they differ from other non-metallic and metallic minerals.

At the very commencement we are faced with a subject on which mineralogists and geologists are by no means in full agreement, and there seems just ground for considerable divergence of opinion, according to the line of argument taken. It is a most remarkable fact that, precious as are certain stones, they do not (with a few exceptions) contain any of the rarer metals, such as platinum, gold, etc., or any of their compounds, but are composed entirely of the common elements and their derivatives, especially of those elements contained in the upper crust of the earth, and this notwithstanding the fact that gems are often found deep down in the earth. This is very significant, and points to the conclusion that these stones were formed by the slow percolation of water from the surface through the deeper parts of the earth, carrying with it, in solution or suspension, the chemical constituents of the earth's upper crust; time and long-

continued pressure, combined with heat or cold, or perhaps both in turn, doing the rest, as already mentioned.

The moisture falling in dew and rain becomes acidulated with carbonic acid, CO_2 (carbon dioxide), from the combustion and decay of organic matter, vegetation, and other sources, and this moisture is capable of dissolving certain calcareous substances, which it takes deep into the earth, till the time comes when it enters perhaps a division-plane in some rock, or some such cavity, and is unable to get away. The hollow becomes filled with water, which is slowly more and more charged with the salts brought down, till saturated; then super-saturated, so that the salts become precipitated, or perhaps crystallised out, maybe by the presence of more or other salts, or by a change in temperature. These crystals then become packed hard by further supplies and pressure, till eventually, after the lapse of ages, a natural gem is found, *exactly filling* the cavity, and is a precious find in many cases.

If now we try to find its analogy in chemistry, and for a moment consider the curious behaviour of some well-known salts, under different conditions of temperature, what is taking place underground ceases to be mysterious and becomes readily intelligible.

Perhaps the best salt for the purpose, and one easy to obtain for experiment, is the sulphate of sodium—known also as Glauber's Salt.

It is in large, colourless prisms, which may soon be dissolved in about three parts of water, so long as the water does not exceed 60° F., and at this temperature a super-saturated solution may easily be made. But if the

water is heated the salt then becomes more and more insoluble as the temperature increases, till it is completely insoluble.

If a super-saturated solution of this Glauber's Salt is made in a glass, at ordinary atmospheric temperature, and into this cold solution, without heating, is dropped a small crystal of the same salt, there will be caused a rise in temperature, and the whole will then crystallise out quite suddenly; the water will be absorbed, and the whole will solidify into a mass which exactly fits the inner contour of the vessel.

We have now formed what *might* be a precious stone, and no doubt would be, if continuous pressure could be applied to it for perhaps a few thousand years; at any rate, the formation of a natural jewel is not greatly different, and after being subjected for a period, extending to ages, to the washings of moisture, the contact of its containing bed (its later matrix), the action of the changes in the temperature of the earth in its vicinity, it emerges by volcanic eruption, earthquake, landslip and the like, or is discovered as a rare and valuable specimen of some simple compound of earth-crust and water, as simple as Glauber's Salt, or as the pure crystallised carbon.

It is also curious to note that in some cases the stones have not been caused by aqueous deposit in an already existing hollow, but the aqueous infusion has acted on a portion of the rock on which it rested, absorbing the rock, and, as it were, replacing it by its own substance. This is evidenced in cases where gems have been found encrusted on their matrix, which latter was being slowly transformed to the character of the jewel encrusted, or "scabbed" on it.

The character of the matrix is also in a great measure the cause of the variety of the stone, for it is obvious that the same salt-charged aqueous solution which undergoes change in and on ironstone would result in an entirely different product from that resting on or embedded in silica.

Following out the explanation of the aqueous solution, in which the earth-crust constituents are secreted, we find that the rarer and more precious metals do not generally enter into the composition of precious stones—which fact may advisedly be repeated. It is, of course, to be expected that beryllium will be found in the emerald, since it is under the species beryl, and zirconium in zircon ; but such instances are the exception, and we may well wonder at the actions of the infinite powers of nature, when we reflect that the rarest, costliest and most beautiful of all precious stones are the simplest in their constituents.

Thus we find the diamond standing unique amongst all gems in being composed of one element only—carbon —being pure crystallised carbon ; a different form from graphite, it is true, but, nevertheless, pure carbon and nothing else. Therefore, from its chemical, as well as from its commercial aspect, the diamond stands alone as the most important of gems.

The next in simplicity, whilst being the most costly of all, is the ruby, and with this may be classed the blue sapphire, seeing that their chemical constituents are exactly the same, the difference being one of colour only. These have two elements, oxygen and aluminium, which important constituents appear also in other stones, but

this example is sufficient to prove their simplicity of origin.

Another unique stone is the turquoise, in that it is the only rare gem essentially containing a great proportion of water, which renders it easily liable to destruction, as we shall see later. It is a combination of alumina, water, and phosphoric acid, and is also unique in being the only known valuable stone containing a phosphate.

Turning to the silica series, we again find a number of gems with two elements only, silica—an important constituent of the earth's crust—and oxygen—an important constituent of atmospheric air. In this group may be mentioned the opal, amethyst, agate, rock-crystal, and the like, as the best known examples, whilst oxygen appears also mostly in the form of oxides, in chrysoberyl, spinel, and the like. This silica group is extremely interesting, for in it, with the exception of the tourmaline and a few others, the composition of the gems is very simple, and we find in this group such stones as the chrysolite, several varieties of topaz, the garnet, emerald, etc., etc.

Malachite and similar stones are more ornamental than precious, though they come in the category of precious stones. These are the carbonate series, containing much carbonic acid, and, as may be expected, a considerable proportion of water in their composition, which water can, of course, be dispelled by the application of heat, but to the destruction of the stone.

From all this will be seen how strong is the theory of aqueous percolation, for, given time and pressure, water charged with earth-crust constituents appears to be the

origin of the formation of all precious stones; and all the precious stones known have, when analysed, been found to be almost exclusively composed of upper-earth-crust constituents; the other compounds which certain stones contain may, in all cases, be traced to their matrix, or to their geological or mineralogical situation.

In contradistinction to this, the essentially underground liquids, with time and pressure, form metallic minerals and mineralise the rocks, instead of forming gems.

Thus we see that in a different class of minerals—compounds of metals with the sulphates, such as sulphuric acid and compounds; also those containing the metallic sulphides; in cases where the metalliferous ores or the metallic elements enter into composition with the halogens —bromine, chlorine, fluorine, and iodine—in all these, precious stones are comparatively common, but the stones of these groups are invariably those used for decorative or ornamental purposes, and true "gems" are entirely absent.

It would therefore appear that though metallic minerals, as already mentioned, are formed by the action of essentially *underground* chemically-charged water—combined with ages of time and long-continued pressure, rocks and earth being transformed into metalliferous ores by the same means—precious stones (or that portion of them ranking as jewels or gems) must on the contrary be wholly, or almost wholly, composed of *upper*-earth-crust materials, carried deep down by water, and subjected to the action of the same time and pressure; the simpler the compound, the more perfect and important the result, as seen in the diamond, the ruby, and the like.

CHAPTER III.

PHYSICAL PROPERTIES.

A—Crystalline Structure.

Before proceeding to the study of precious stones as individual gems, certain physical properties common to all must be discussed, in order to bring the gems into separate classes, not only because of some chemical uniformity, but also because of the unity which exists between their physical formation and properties.

The first consideration, therefore, may advisedly be that of their crystals, since their crystalline structure forms a ready means for the classification of stones, and indeed for that of a multitudinous variety of substances.

It is one of the many marvellous phenomena of nature that mineral, as well as many vegetable and animal substances, on entering into a state of solidity, take upon themselves a definite form called a crystal. These crystals build themselves round an axis or axes with wonderful regularity, and it has been found, speaking broadly, that the same substance gives the same crystal, no matter how its character may be altered by colour or other means. Even when mixed with other crystallisable substances, the resulting crystals may partake of the two varieties and become a sort of composite, yet to the physicist they are read like an open book, and when

separated by analysis they at once revert to their original form. On this property the analyst depends largely for his results, for in such matters as food adulteration, etc., the microscope unerringly reveals impurities by means of the crystals alone, apart from other evidences.

It is most curious, too, to note that no matter how large a crystal may be, when reduced even to small size it will be found that the crystals are still of the same shape. If this process is taken still further, and the substance is ground to the finest impalpable powder, as fine as floating dust, when placed under the microscope each speck, though perhaps invisible to the naked eye, will be seen a perfect crystal, of the identical shape as that from which it came, one so large maybe that its planes and angles might have been measured and defined by rule and compass. This shows how impossible it is to alter the shape of a crystal. We may dissolve it, pour the solution into any shaped vessel or mould we desire, recrystallise it and obtain a solid sphere, triangle, square, or any other form; it is also possible, in many cases, to squeeze the crystal by pressure into a tablet, or any form we choose, but in each case we have merely altered the *arrangement* of the crystals, so as to produce a differently shaped *mass*, the crystals themselves remaining individually as before. Such can be said to be one of the laws of crystals, and as it is found that every substance has its own form of crystal, a science, or branch of mineralogy, has arisen, called "crystallography," and out of the conglomeration of confused forms there have been evolved certain rules of comparison by which all known crystals may be classed in certain groups.

This is not so laborious a matter as would appear, for if we take a substance which crystallises in a cube we find it is possible to draw nine symmetrical planes, these being called "planes of symmetry," the intersections of one or more of which planes being called "axes of symmetry." So that in the nine planes of symmetry of the cube we get three axes, each running through to the opposite side of the cube. One will be through the centre of a face to the opposite face ; a second will be through the centre of one edge diagonally ; the third will be found in a line running diagonally from one point to its opposite. On turning the cube on these three axes—as, for example, a long needle running through a cube of soap—we shall find that four of the six identical faces of the cube are exposed to view during each revolution of the cube on the needle or axis.

These faces are not necessarily, or always, planes, or flat, strictly speaking, but are often more or less curved, according to the shape of the crystal, taking certain characteristic forms, such as the square, various forms of triangles, the rectangle, etc., and though the crystals may be a combination of several forms, all the faces of any particular form are similar.

All the crystals at present known exhibit differences in their planes, axes and lines of symmetry, and on careful comparison many of them are found to have some features in common ; so that when they are sorted out it is seen that they are capable of being classified into thirty-three groups. Many of these groups are analogous, so that on analysing them still further we find that all the known crystals may be classed in six separate systems

according to their planes of symmetry, and all stones of the same class, no matter what their variety or complexity may be, show forms of the same group. Beginning with the highest, we have—(1) the cubic system, with nine planes of symmetry ; (2) the hexagonal, with seven planes ; (3) the tetragonal, with five planes ; (4) the rhombic, with three planes ; (5) the monoclinic, with one plane ; (6) the triclinic, with no plane of symmetry at all.

In the first, the cubic—called also the isometric, monometric, or regular—there are, as we have seen, three axes, all at right angles, all of them being equal.

The second, the hexagonal system—called also the rhombohedral—is different from the others in having four axes, three of them equal and in one plane and all at 120° to each other ; the fourth axis is not always equal to these three. It may be, and often is, longer or shorter. It passes through the intersecting point of the three others, and is perpendicular or at right angles to them.

The third of the six systems enumerated above, the tetragonal—or the quadratic, square prismatic, dimetric, or pyramidal—system has three axes like the cubic, but, in this case, though they are all at right angles, two only of them are equal, the third, consequently, unequal. The vertical or principal axis is often much longer or shorter in this group, but the other two are always equal and lie in the horizontal plane, at right angles to each other, and at right angles to the vertical axis.

The fourth system, the rhombic—or orthorhombic, or prismatic, or trimetric—has, like the tetragonal, three axes ; but in this case, none of them are equal, though the two lateral axes are at right angles to each other, and

to the vertical axis, which may vary in length, more so even than the other two.

The fifth, the monoclinic—or clinorhombic, monosymmetric, or oblique—system, has also three axes, all of them unequal. The two lateral axes are at right angles to each other, but the principal or vertical axis, which passes through the point of intersection of the two lateral axes, is only at right angles to one of them.

In the sixth and last system, the triclinic—or anorthic, or asymmetric—the axes are again three, but in this case, none of them are equal and none at right angles.

It is difficult to explain these various systems without drawings, and the foregoing may seem unnecessarily technical. It is, however, essential that these particulars should be clearly stated in order thoroughly to understand how stones, especially uncut stones, are classified. These various groups must also be referred to when dealing with the action of light and other matters, for in one or other of them most stones are placed, notwithstanding great differences in hue and character; thus all stones exhibiting the same crystalline structure as the diamond are placed in the same group. Further, when the methods of testing come to be dealt with, it will be seen that these particulars of grouping form a certain means of testing stones and of distinguishing spurious from real. For if a stone is offered as a real gem (the true stone being known to lie in the highest or cubic system), it follows that should examination prove the stone to be in the sixth system, then, no matter how coloured or cut, no matter how perfect the imitation, the test of its crystalline structure stamps it readily as false beyond all shadow of

doubt—for as we have seen, no human means have as yet been forthcoming by which the crystals can be changed in form, only in arrangement, for a diamond crystal *is* a diamond crystal, be it in a large mass, like the brightest and largest gem so far discovered—the great Cullinan diamond—or the tiniest grain of microscopic diamond-dust, and so on with all precious stones. So that in future references, to avoid repetition, these groups will be referred to as group 1, 2, and so on, as detailed here.

A

CHAPTER IV.

PHYSICAL PROPERTIES.

B—Cleavage.

By cleavage is meant the manner in which minerals separate or split off with regularity. The difference between a break or fracture and a "cleave," is that the former may be anywhere throughout the substance of the broken body, with an extremely remote chance of another fracture being identical in form, whereas in the latter, when a body is "cleaved," the fractured part is more readily severed, and usually takes a similar if not an actually identical form in the divided surface of each piece severed. Thus we find a piece of wood may be "broken" or "chopped" when fractured across the grain, no two fractured edges being alike; but, strictly speaking, we only "cleave" wood when we "split" it with the grain, or, in scientific language, along the line of cleavage, and then we find many pieces with their divided surfaces identical. So that when wood is "broken," or "chopped," we obtain pieces of any width or thickness, with no manner of regularity of fracture, but when "cleaved," we obtain strips which are often perfectly parallel, that is, of equal thickness throughout their whole length, and of such uniformity of surface that it is difficult or even impossible to distinguish one

strip from another. Advantage is taken of these lines of cleavage to procure long and extremely thin even strips from trees of the willow variety for such trades as basket-making.

The same effect is seen in house-coal, which may easily be split the way of the grain (on the lines of cleavage), but is much more difficult and requires greater force to break across the grain. Rocks also show distinct lines of cleavage, and are more readily split one way than another, the line of cleavage or stratum of break being at any angle and not necessarily parallel to its bed. A striking example of this is seen in slate, which may be split in plates, or laminæ, with great facility, though this property is the result of the pressure to which the rock has been for ages subjected, which has caused a change in the molecules, rather than by "cleavage" as the term is strictly understood, and as existing in minerals. Mica is also another example of laminated cleavage, for given care, and a thin, fine knife to divide the plates, this mineral may be "cleaved" to such remarkably thin sheets as to be unable to sustain the most delicate touch without shattering.

These are well-known examples of simple cleavage, in one definite direction, though in many instances there are several forms and directions of cleavage, but even in these there is generally one part or line in and on which cleavage will take place much more readily than on the others, these planes or lines also showing different properties and angular characters, which, no matter how much fractured, always remain the same. It is this "cleavage" which causes a crystal to reproduce itself

exactly, as explained in the last chapter, showing its parent form, shape and characteristics with microscopic perfection, but more and more in miniature as its size is reduced.

This may clearly be seen by taking a very small quantity of such a substance as chlorate of potash. If a crystal of this is examined under a magnifying glass till its crystalline form and structure are familiar, and it is then placed in a test-tube and gently heated, cleavage will at once be evident. With a little crackling, the chlorate splits itself into many crystals along its chief lines of cleavage (called the cleavage planes), every one of which crystals showing under the microscope the identical form and characteristics of the larger crystal from which it came.

The cleavage of minerals must, therefore, be considered as a part of their crystalline structure, since this is caused by cleavage, so that both cleavage and crystalline structure should be considered together. Thus we see that given an unchangeable crystal with cleavage planes evident, it is possible easily to reproduce the same form over and over again by splitting, whereas by simply breaking, the form of the crystal would be lost; just as a rhomb of Iceland spar might be sawn or broken across the middle and its form lost, although this would really be more apparent than real, since it would be an alteration in the mass and not in the shape of each individual crystal. And given further cleavage, by time or a sudden breaking down, even the mass, as mass, would eventually become split into smaller but perfect rhombs.

Much skill is, therefore, required in cutting and

fashioning a precious stone, otherwise the gem may be ruined at the onset, for it will only divide along its lines of cleavage, and any mistake in deciding upon these, would "break," not "split" the stone, and destroy the beauty of its crystalline structure. An example of this was specially seen in the great Cullinan diamond, the splitting of which was perhaps the most thrilling moment in the history of precious stones.* The value of the enormous crystal was almost beyond computation, but it had a flaw in the centre, and in order to cut out this flaw it was necessary to divide the stone into two pieces. The planes of cleavage were worked out, the diamond was sawn a little, when the operator, acknowledged to be the greatest living expert, inserted a knife in the saw-mark, and with the second blow of a steel rod, the marvellous stone parted precisely as intended, cutting the flaw exactly in two, leaving half of it on the outside of each divided portion. The slightest miscalculation would have meant enormous loss, if not ruin, to the stone, but the greatest feat the world has ever known in the splitting of a priceless diamond was accomplished successfully by this skilful expert in an Amsterdam workroom in February, 1908. Some idea of the risk involved may be gathered from the fact that this stone, the largest ever discovered, in the rough weighed nearly 3,254 carats, its value being almost anything one cared to state—incalculable.

* The hammer and knife used in cutting the diamond, the two largest pieces of which are now called "The Stars of Africa," together with a model of the great uncut stone, are in the Tower of London amongst the Regalia.

These cleavage planes help considerably in the bringing of the stone to shape, for in a broad sense, a finished cut stone may be said to be in the form in which its cleavages bring it. Particularly is this seen in the diamond "brilliant," which plainly evidences the four cleavage planes. These cleavage planes and their number are a simple means of identification of precious stones, though those possessing distinct and ready cleavages are extremely liable to "start" or "split" on these planes by extremes of heat and cold, accidental blows, sudden shocks and the like.

In stones possessing certain crystalline structure, the cleavage planes are the readiest, often the only, means of identification, especially when the stones are chemically coloured to imitate a more valuable stone. In such cases the cleavage of one stone is often of paramount importance in testing the cleavage of another, as is seen in the perfection of the cleavage planes of calcite, which is used in the polariscope.

It sometimes happens, however, that false conditions arise, such as in substances which are of no form or shape, and are in all respects and directions without regular structure and show no crystallisation even in the minutest particles; these are called amorphous. Such a condition sometimes enters wholly or partially into the crystalline structure, and the mineral loses its true form, possessing instead the form of crystals, but without a crystalline structure. It is then called a pseudomorph, which is a term applied to any mineral which, instead of having the form it should possess, shows the form of something which has altered its structure completely, and then disappeared. For

instance: very often, in a certain cavity, fluorspar has existed originally, but, through some chemical means, has been slowly changed to quartz, so that, as crystals cannot be changed in shape, we find quartz existing—undeniably quartz—yet possessing the crystals of fluorspar; therefore the quartz becomes a pseudomorph, the condition being an example of what is termed pseudomorphism. The actual cause of this curious chemical change or substitution is not known with certainty, but it is interesting to note the conditions in which such changes do occur.

It is found that in some cases, the matrix of a certain shaped crystal may, after the crystal is dissolved or taken away, become filled by some other and foreign substance, perhaps in liquid form; or a crystalline substance may become coated or "invested" by another foreign substance, which thus takes its shape; or actual chemical change takes place by means of an incoming substance which slowly alters the original substance, so that eventually each is false and both become pseudomorphs. This curious change often takes place with precious stones, as well as with other minerals, and to such an extent that it sometimes becomes difficult to say what the stone ought really to be called.

Pseudomorphs are, however, comparatively easy of isolation and detection, being more or less rounded in their crystalline form, instead of having sharp, well-defined angles and edges; their surfaces also are not good. These stones are of little value, except in the specially curious examples, when they become rare more by reason of their curiosity than by their utility as gems.

Some also show cleavage planes of two or more

systems, and others show a crystalline structure comprised of several systems. Thus calcspar is in the 2nd, or hexagonal, whilst aragonite is in the 4th, the rhombic, system, yet both are the same substance, viz. :—carbonate of lime. Such a condition is called dimorphism ; those minerals which crystallise in three systems are said to be trimorphous. Those in a number of systems are polymorphous, and of these sulphur may be taken as an example, since it possesses thirty or more modifications of its crystalline structure, though some authorities eliminate nearly all these, and, since it is most frequently in either the 4th (rhombic) or the 5th (monoclinic) systems, consider it as an example of dimorphism, rather than polymorphism.

These varieties of cleavage affect the character, beauty and usefulness of the stone to a remarkable extent, and at the same time form a means of ready and certain identification and classification.

CHAPTER V.

PHYSICAL PROPERTIES.

C—Light.

Probably the most important of the many important physical properties possessed by precious stones are those of light and its effects, for to these all known gems owe their beauty, if not actual fascination.

When light strikes a cut or polished stone, one or more of the following effects are observed:—it may be transmitted through the stone, diaphaneity, as it is called; it may produce single or double refraction, or polarisation; if reflected, it may produce lustre or colour; or it may produce phosphorescence; so that light may be (1) transmitted; (2) reflected; or produce (3) phosphorescence.

(1) Transmission.—In transmitted light we have, as stated above, single or double refraction, polarisation, and diaphaneity.

To the quality of *refraction* is due one of the chief charms of certain precious stones. It is not necessary to explain here what refraction is, for everyone will be familiar with the refractive property of a light-beam when passing through a medium denser than atmospheric air. It will be quite sufficient to say that all the rays are not equal in refractive power in all substances, so

that the middle of the spectrum is generally selected as the mean for indexing purposes.

It will be seen that the stones in the 1st, or cubic system, show single refraction, whereas those of all other systems show double refraction ; thus, light, in passing through their substance, is deviated, part of it going one way, the other portion going in another direction—that is, at a slightly different angle—so that this property alone will isolate readily all gems belonging to the 1st system.

A well-known simple experiment in physics shows this clearly. A mark on a card or paper is viewed through a piece of double-refracting spar (Iceland spar or clear calcite), when the mark is doubled and two appear. On rotating this rhomb of spar, one of these marks is seen to revolve round the other, which remains stationary, the moving mark passing further from the centre in places. When the spar is cut and used in a certain direction, we see but one mark, and such a position is called its optical axis.

Polarisation is when certain crystals possessing double refraction have the power of changing light, giving it the appearance of poles which have different properties, and the polariscope is an instrument in which are placed pieces of double-refracting (Iceland) spar, so that all light passing through will be polarised.

Since only crystals possessing the property of double refraction show polarisation, it follows that those of the 1st, or cubic system—in which the diamond stands a prominent example—fail to become polarised, so that when such a stone is placed in the polariscope and

rotated, it fails *at every point* to transmit light, which a double-refracting gem allows to pass except when its optical axis is placed in the axis of the polariscope, but this will be dealt with more fully when the methods of testing the stones come to be considered.

Diaphaneity, or the power of transmitting light:—some rather fine trade distinctions are drawn between the stones in this class, technical distinctions made specially for purposes of classification, thus:—a "non-diaphanous" stone is one which is quite opaque, no light of any kind passing through its substance; a "diaphanous" stone is one which is altogether transparent; "semi-diaphanous" means one not altogether transparent, and sometimes called "sub-transparent." A "translucent" stone is one in which, though light passes through its substance, sight is not possible through it; whilst in a "sub-translucent" stone, light passes through it, but only in a small degree.

The second physical property of light is seen in those stones which owe their beauty or value to REFLECTION: this again may be dependent on Lustre, or Colour.

Lustre.—This is an important characteristic due to reflection, and of which there are six varieties:—(α) adamantine (which some authorities, experts and merchants subdivide as detailed below); (β) pearly; (γ) silky; (δ) resinous; (ϵ) vitreous; (ζ) metallic. These may be described:—

(α) Adamantine, or the peculiar lustre of the diamond, so called from the lustre of adamantine spar, which is a form of corundum (as is emery) with a diamond-like

lustre, the hard powder of which is used in polishing diamonds. It is almost pure anhydrous alumina (Al_2O_3) and is, roughly, four times as heavy as water. The lustre of this is the true "adamantine," or diamond, brilliancy, and the other and impure divisions of this particular lustre are: *splendent*, when objects are reflected perfectly, but of a lower scale of perfection than the true "adamantine" standard, which is absolutely flawless. When still lower, and the reflection, though maybe fairly good, is somewhat "fuzzy," or is confused or out of focus, it is then merely *shining*; when still less distinct, and no trace of actual reflection is possible (by which is meant that no object can be reproduced in any way to define it, as it could be defined in the reflection from still water or the surface of a mirror, even though imperfectly) the stone is then said to *glint* or *glisten*. When too low in the scale even to glisten, merely showing a feeble lustre now and again as the light is reflected from its surface in points which vary with the angle of light, the stone is then said to be *glimmering*. Below this, the definitions of lustre do not go, as such stones are said to be *lustreless*.

(β) Pearly, as its name implies, is the lustre of a pearl.

(γ) Silky, possessing the sheen of silk, hence its name.

(δ) Resinous, also explanatory in its name; amber and the like come in this variety.

(ε) Vitreous. This also explains itself, being of the lustre of glass, quartz, etc.; some experts subdividing this for greater defining accuracy into the "sub-vitreous" or lower type, for all but perfect specimens.

(ζ) Metallic or Sub-metallic. The former when the lustre is perfect as in gold ; the latter when the stones possess the less true lustre of copper.

Colour.—Colour is an effect entirely dependent upon light, for in the total absence of light, such as in black darkness, objects are altogether invisible to the normal human eye. In daylight, also, certain objects reflect so few vibrations of light, or none, that they appear grey, black, or jet-black ; whilst those which reflect all the rays of which light is composed, and in the same number of vibrations, appear white. Between these two extremes of *none* and *all* we find a wonderful play and variety of colour, as some gems allow the red rays only to pass and therefore appear red ; others allow the blue rays only and these appear blue, and so on, through all the shades, combinations and varieties of the colours of which light is composed, as revealed by the prism. But this is so important a matter that it demands a chapter to itself.

The third physical property of light, PHOSPHORESCENCE, is the property possessed by certain gems and minerals of becoming phosphorescent on being rubbed, or on having their temperature raised by this or other means.

It is difficult to say exactly whether this is due to the heat, the friction, or to electricity. Perhaps two or all of these may be the cause, for electricity is developed in some gems—such as the topaz—by heat, and heat by electricity, and phosphorescence developed by both.

For example, if we rub together some pulverised fluor-spar in the dark, or raise its temperature by the direct application of heat, such as from a hot or warm iron, or

a heated wire, we at once obtain excellent phosphorescence. Common quartz, rubbed against a second piece of the same quartz in the dark, becomes highly phosphorescent. Certain gems, also, when merely exposed to light—sunlight for preference—then taken into a darkened room, will glow for a short time. The diamond is one of the best examples of this kind of phosphorescence, for if exposed to sunlight for a while, then covered and rapidly taken into black darkness, it will emit a curious phosphorescent glow for from one to ten seconds ; the purer the stone, the longer, clearer and brighter the result.

CHAPTER VI.

PHYSICAL PROPERTIES.

D—Colour.

Colour is one of the most wonderful effects in nature. It is an attribute of light and is not a part of the object which appears to be coloured ; though all objects, by their chemical or physical composition, determine the number and variety of vibrations passed on or returned to the eye, thus fixing their own individual colours.

We have also seen that if an *equal* light-beam becomes obstructed in its passage by some substance which is denser than atmospheric air, it will become altered in its direction by refraction or reflection, and polarised, each side or pole having different properties.

Polarised light cannot be made again to pass in a certain direction through the crystal which has polarised it ; nor can it again be reflected at a particular angle ; so that in double-refracting crystals, these two poles, or polarised beams, are different in colour, some stones being opaque to one beam but not to the other, whilst some are opaque to both.

This curious phenomenon, with this brief, though somewhat technical explanation, shows the cause of many of the great charms in precious stones, for when viewed at one angle they appear of a definite colour, whilst at

another angle they are just as decided in their colour, which is then entirely different; and as these angles change as the eye glances on various facets, the stone assumes a marvellous wealth of the most brilliant and intense colour of kaleidoscopic variety, even in a stone which may itself be absolutely clear or colourless to ordinary light.

Such an effect is called pleochroism, and crystals which show variations in their colour when viewed from different angles, or by transmitted light, are called pleochroic, or pleochromatic—from two Greek words signifying "to colour more." To aid in the examination of this wonderfully beautiful property possessed by precious stones, a little instrument has been invented called the dichroscope, its name showing its Greek derivation, and meaning—"to see colour twice" (twice, colour, to see). It is often a part of a polariscope; frequently a part also of the polarising attachment to the microscope, and is so simple and ingenious as to deserve detailed explanation.

In a small, brass tube is fixed a double-image prism of calcite or Iceland spar, which has been achromatised—that is, clear, devoid of colour—and is therefore capable of transmitting light without showing any prismatic effect, or allowing the least trace of any except the clear light-beam to pass through. At one end of this tube there is a tiny square hole, the opposite end carrying a small convex lens, of such a strength or focus as to show the square hole in true focus, that is, with perfectly sharp definition, even up to the corners of the square. On looking through the tube, the square hole is duplicated two squares being seen. The colours of a gem are tested

by the stone being put in front of this square, when the two colours are seen quite distinctly. Not only is this a simple means of judging colour, but it enables a stone to be classified readily. For if the dichroscope shows two images of *the same* colour, then it may possibly be a carbuncle, or a diamond, as the case may be—for single-refracting stones, of the first or cubic system, show two images of *the same* colour. But if these two colours are different, then it must be a double-refracting stone, and according to the particular colours seen, so is the stone classified, for each stone has its own identical colour or colours when viewed through this small but useful instrument.

How clear and distinct are these changes may be viewed without it in substances strongly dichroic; for instance, if common mica is viewed in one direction, it is transparent as polished plate-glass, whilst at another angle, it is totally opaque. Chloride of palladium also is blood-red when viewed parallel to its axis, and transversely, it is a remarkably bright green. The beryl also, is sea-green one way and a beautiful blue another; the yellow chrysoberyl is brown one way and yellow with a greenish cast when viewed another way. The pink topaz shows rose-colour in one direction and yellow in another. These are perhaps the most striking examples, and are mostly self-evident to the naked eye, whilst in other cases, the changes are so delicate that the instrument must be used to give certainty; some again show changes of colour as the stone is revolved in the dichroscope, or the instrument revolved round the stone.

Some stones, such as the opal, split up the light-beams

as does a prism, and show a wonderful exhibition of prismatic colour, which is technically known as a "play of colour." The descriptive term "opalescence" is self-suggesting as to its origin, which is the "noble" or "precious" opal; this radiates brilliant and rapidly changing iridescent reflections of blue, green, yellow and red, all blending with, and coming out of, a curious silky and milky whiteness, which is altogether characteristic. The moonstone is another example of this peculiar feature which is possessed in a more or less degree by all the stones in the class of pellucid jewels, but no stone or gem can in any way even rival the curious mixture of opaqueness, translucency, silkiness, milkiness, fire, and the steadfast changeable and prismatic brilliance of colour of the precious opal. The other six varieties of opal are much inferior in their strange mixture of these anomalies of light and colour. Given in order of value, we have as the second, the "fire" opal with a red reflection, and, as a rule, that only. The third in value is the "common" opal, with the colours of green, red, white and yellow, but this is easily distinguishable from the "noble" or "precious" variety in that the common opal does not possess that wonderful "play" of colour. The fourth variety is called the "semi-opal," which is really like the third variety, the "common," but of a poorer quality and more opaque. The fifth variety in order of value, is that known as the "hydrophane," which has an interesting characteristic in becoming transparent when immersed in water, and only then. The sixth is the "hyalite," which has but a glassy or vitreous lustre, and is found almost exclusively in the form of globules, or clusters of globules,

somewhat after the form and size of bunches of grapes; hence the name "botryoidal" is often applied to this variety. The last and commonest of all the seven varieties of opal is somewhat after the shape of a kidney (reniform), or other irregular shape, occasionally almost transparent, but more often somewhat translucent, and very often opaque. This seventh class is called "menilite," being really an opaline form of quartz, originally found at Menilmontant, hence its name (*Menil*, and Greek *lithos*, stone). It is a curious blue on the exterior of the stone, brown inside.

History records many magnificent and valuable opals, not the least of which was that of Nonius, who declined to give it to Mark Antony, choosing exile rather than part with so rare a jewel, which Pliny describes as being existent in his day, and of a value which, in present English computation, would exceed one hundred thousand pounds.

Many other stones possess one or more properties of the opal, and are therefore considered more or less opalescent. This "play of colour" and "opalescence," must not be confused with "change of colour." The two first appear mostly in spots and in brilliant points or flashes of coloured light, or "fire" as it is termed. This fire is constantly on the move, or "playing," whereas "change of colour," though not greatly dissimilar, is when the fire merely travels over broader surfaces, each colour remaining constant, such as when directly moving the stone, or turning it, when the broad mass of coloured light slowly changes, usually to its complementary. Thus in this class of stone, subject to "change of colour," a

green light is usually followed by its complementary, red, yellow by purple, blue by orange, green by brown, orange by grey, purple by broken green, with all the intermediary shades of each.

Thus when the line of sight is altered, or the stone moved, never otherwise, the colours chase one another over the surface of the gem, and mostly in broad splashes ; but in those gems possessing "play of colour," strictly speaking, whilst the stone itself remains perfectly still, and the sight is fixed unwaveringly upon it, the pulsations of the blood in the eyes, with the natural movements of the eyes and eyelids, even in a fixed, steady glance, are quite sufficient to create in the stone a display of sparks and splashes of beautiful fiery light and colour at every tremor.

The term "iridescence" is used when the display of colour is seen on the surface, rather than coming out of the stone itself. The cause of this is a natural, or in some cases an accidental, breaking of the surface of the stone into numerous cobweb-like cracks ; these are often of microscopic fineness, only perceptible under moderately high powers. Nevertheless they are quite sufficient to interfere with and refract the light rays and to split them up prismatically. In some inferior stones this same effect is caused or obtained by the application of a gentle heat, immersion in chemicals, subjection to "X rays" and other strong electric influence, and in many other ways. As a result, the stone is very slightly expanded, and as the molecules separate, there appear on the surface thousands, perhaps millions, of microscopic fissures running at all angles, so that no matter from what position

the stone may be viewed, a great number of these fissures are certain to split up the light into prismatic colours causing brilliant iridescence. Similar fissures may often be seen with the naked eye on glass, especially if scorched or cooled too rapidly (chilled), and on the surface of clear spar and mica, their effects being of extreme interest, from a colour point of view, at least.

CHAPTER VII.

PHYSICAL PROPERTIES.

E—Hardness.

Hardness is perhaps one of the most important features in a stone, especially those of the "gem" series, for no matter how colour, lustre, general beauty and even rarity may entitle a stone to the designation "precious," unless it possesses great hardness it cannot be used as a gem or jewel.

Consequently, the hardness of jewels is a matter of no small importance, and by dint of indefatigable research, in tests and comparison, all known precious stones have been classified in various scales or degrees of hardness. The most popular and reliable table is that of Mohs, in which he takes talc as the softest of the rarer minerals and classes this as No. 1; from that he goes by gradual steps to the diamond, the hardest of the stones, which he calls No. 10, and between these two all other gems are placed. Here is given a complete list of Mohs's arrangement of stones, according to their hardness, beginning at No. 1, thus :—

Talc	1	Malachite	3½
Rock salt	2	Jet	3½
Amber	2½	Fluorspar	4
Calcite	3	Apatite	5

Dioptase	5
Kyanite (various)	5–7
Haüynite	5½
Hæmatite	5½
Lapis lazuli	5½
Moldavite (various)	5½–6½
Rhodonite	5½–6½
Obsidian	5½
Sphene	5½
Opal (various)	5½–6½
Nephrite	5¾
Chrysolite	6-7
Felspar	6
Adularia	6
Amazon stone	6
Diopside	6
Iron pyrites	6
Labradorite	6
Turquoise	6
Spodumene	6½–7
The Chalcedony group, which embraces the Agate, Carnelian, etc.	6½
Demantoid	6½
Epidote	6½
Idocrase	6½
Garnets (see also "Red Garnets" below)	6½–7½
Axinite	6¾
Jadeite	6¾
Quartz, including Rock-crystal, Amethyst, Jasper, Chrysoprase, Citrine, etc.	7
Jade	7
Dichorite (water sapphire)	7–7½
Cordierite	7¼
Red Garnets (see also "Garnets" above)	7¼
Tourmaline	7¼
Andalusite	7½
Euclase	7½
Staurolite	7½
Zircon	7½
Emerald, Aquamarine, or Beryl	7¾
Phenakite	7¾
Spinel	8
Topaz	8
Chrysoberyl	8½
The Corundum group, embracing the Ruby, Sapphire, etc.	9
Diamond	10

(See also list of stones, arranged in their respective colours, in Chapter XII.)

The method of testing is very simple. A representative selection of the above stones, each with a sharp edge, is kept for the purpose of scratching and being scratched, and those usually set apart for tests in the various groups, are as follows :—

1	Talc	6	Felspar
2	Rock-salt, or Gypsum	7	Quartz
3	Calcite	8	Topaz
4	Fluorspar	9	Corundum
5	Apatite	10	Diamond

The stone under examination may perhaps first be somewhat roughly classified by its colour, cleavage, and general shape. One of these standard stones is then gently rubbed across its surface and then others of increasingly higher degrees, till no scratch is evident under a magnifying glass. Thus if quartz ceases to scratch it, but a topaz will do so, the degree of hardness must lie between 7 and 8. Then we reverse the process: the stone is passed over the standard, and if both quartz and topaz are scratched, then the stone is at least equal in hardness to the topaz, and its classification becomes an easy matter.

Instead of stones, some experts use variously-tempered needles of different qualities and compositions of iron and steel. For instance, a finely-tempered ordinary steel needle will cut up to No. 6 stones; one made of tool steel, up to 7; one of manganese steel, to 7½; one made of high-speed tool steel, to 8 and 8½, and so on, according to temper; so that from the scratch which can be made with the finger-nail on mica, to the hardness of the diamond, which diamond alone will scratch readily, the stones may be picked out, classified and tested, with unerring accuracy.

It will thus be seen how impossible it is, even in this one of many tests, for an expert to be deceived in the purchase of precious stones, except through gross care-

lessness—a fault seldom, if ever, met with in the trade. For example—a piece of rock-crystal, chemically coloured, and cut to represent a ruby, might appear so like one as to deceive a novice, but the mere application to its surface of a real ruby, which is hardness 9, or a No. 9 needle, would reveal too deep or powdery a scratch; also its possibility of being scratched by a topaz or a No. 8 needle, would alone prove it false, for the corundum group, being harder than No. 8, could not be scratched by it. So would the expert go down the scale, the tiny scratches becoming fainter as he descended, because he would be approaching more nearly the hardness of the stone under test, till he arrived at the felspar, No. 6, which would be too soft to scratch it, yet the stone would scratch the felspar, but not zircon or andalusite, 7½, or topaz, 8, so that his tests would at once classify the stone as a piece of cut and coloured quartz, thus confirming what he would, at the first sight, have suspected it to be.

The standard stones themselves are much more certain in results than the needles, which latter, though well selected and tempered, are not altogether reliable, especially in the more delicate distinctions of picking out the hardest of certain stones of the same kind, in which cases only the expert judge can decide with exactness. Accurate in this the expert always is, for he judges by the sound and depth of his cut, and by the amount and quality of the powder, often calling the microscope to his aid, so that when the decision is made finally, there is never the least doubt about it.

Rapidly as these tests can be made, they are extremely reliable, and should the stone be of great value, it is

also subjected to other unerring tests of extreme severity, any one of which would prove it false, if it chanced to be so, though some stones are manufactured and coloured so cleverly that to all but the expert judge and experienced dealer, they would pass well for the genuine.

In Mohs's list it will be seen that several stones vary considerably, the opal, for instance, having a degree of hardness from $5\frac{1}{2}$ to $6\frac{1}{2}$ inclusive. All stones differ slightly, though almost all may be said to fit their position in the scale; but in the case of the opal, the difference shown is partly due to the many varieties of the stone, as described in the last chapter.

In applying this test of hardness to a cut gem, it will be noticed that some parts of the same stone seem to scratch more readily than others, such as on a facet at the side, which is often softer than those nearest the widest part of the stone, where the claws, which hold it in its setting, usually come. This portion is called the "girdle," and it is on these "girdle" facets that the scratches are generally made. This variation in hardness is mostly caused by cleavage, these cleavage planes showing a marked, though often but slight, difference in the scratch, which difference is *felt* rather than seen. In addition to the peculiar *feel* of a cutting scratch, is the *sound* of it. On a soft stone being cut by a hard one, little or no sound is heard, but there will form a plentiful supply of powder, which, on being brushed off, reveals a more or less deep incision. But as the stones approach one another in hardness, there will be little powder and a considerable increase in the noise; for the harder are the stones, cutting and being cut, the louder will be the

sound and the less the powder. An example of this difference is evident in the cutting of ordinary glass with a "set" or "glazier's" diamond, and with a nail. If the diamond is held properly, there will be heard a curious sound like a keen, drawn-out "kiss," the diamond being considerably harder than the material it cut. An altogether different sound is that produced by the scratching of glass with a nail. In this case, the relative difference in hardness between the two is small, so that the glass can only be scratched and not "cut" by the nail; it is too hard for that, so the noise is much greater and becomes a screech. Experience, therefore, makes it possible to tell to a trifle, at the first contact, of what the stone is composed, and in which class it should be placed, by the mere "feel" of the scratch, the depth of it, the amount and kind of powder it leaves, and above all, by the sound made, which, even in the tiniest scratch, is quite characteristic.

CHAPTER VIII.

PHYSICAL PROPERTIES.

F—Specific Gravity.

The fixing of the specific gravity of a stone also determines its group position with regard to weight; its colour and other characteristics defining the actual stone. This is a safe and very common method of proving a stone, since its specific gravity does not vary more than a point or so in different specimens of the same stone. There are several ways of arriving at this, such as by weighing in balances in the usual manner, by displacement, and by immersion in liquids the specific gravity of which are known. Cork is of less specific gravity than water, therefore it floats on the surface of that liquid, whereas iron, being heavier, sinks. So that by changing the liquid to one lighter than cork, the cork will sink in it as does iron in water; in the second instance, if we change the liquid to one heavier than iron, the iron will float on it as does cork on water, and exactly as an ordinary flat-iron will float on quicksilver, bobbing up and down like a cork in a tumbler of water. If, therefore, solutions of known but varying densities are compounded, it is possible to tell almost to exactitude the specific gravity of any stone dropped into them, by the position they assume. Thus, if we take a solution of

pure methylene iodide, which has a specific gravity of 3·2981, and into this drop a few stones selected indiscriminately, the effect will be curious: first, some will sink plump to the bottom like lead; second, some will fall so far quickly, then remain for a considerable time fairly stationary; third, some will sink very slowly; fourth, some will be partially immersed, that is, a portion of their substance being above the surface of the liquid and a portion covered by it; fifth, some will float on the surface without any apparent immersion. In the first case, the stones will be much heavier than 3·2981; in the second, the stones will be about 3·50; in the third and fourth instances, the stones will be about the same specific gravity as the liquid, whilst in the fifth, they will be much lighter, and thus a rough but tolerably accurate isolation may be made.

On certain stones being extracted and placed in other liquids of lighter or denser specific gravity, as the case may be, their proper classification may easily be arrived at, and if the results are checked by actual weight, in a specific gravity balance, they will be found to be fairly accurate. The solution commonly used for the heaviest stones is a mixture of nitrate of thallium and nitrate of silver. This double nitrate has a specific gravity of 4·7963, therefore such a stone as zircon, which is the heaviest known, will float in it. For use, the mixture should be slightly warmed till it runs thin and clear; this is necessary, because at 60° (taking this as ordinary atmospheric temperature) it is a stiff mass. A lighter liquid is a mixture of iodide of mercury in iodide of potassium, but this is such an extremely corrosive and

dangerous mixture, that the more common solution is one in which methylene iodide is saturated with a mixture of iodoform until it shows a specific gravity of 3·601 ; and by using the methylene iodide alone, in its pure state, it having a specific gravity of 3·2981, the stones to that weight can be isolated, and by diluting this with benzole, its weight can be brought down to that of the benzole itself, as in the case of Sonstadt's solution. This solution, in full standard strength, has a specific gravity of 3·1789, but may be weakened by the addition of distilled water iu varying proportions till the weight becomes almost that of water.

Knowing the specific gravity of all stones, and dividing them into six groups, by taking a series of standard solutions selected from one or other of the above, and of known specific gravity, we can judge with accuracy if any stone is what it is supposed to be, and classify it correctly by its mere floating or sinking when placed in these liquids. Beginning then with the pure double nitrate of silver and thallium, this will isolate the stones of less specific gravity than 4·7963, and taking the lighter solutions and standardising them, we may get seven solutions which will isolate the stones as follows :—

A	shows the stones which have a specific gravity over			4·7963		
B	,,	,,	,,	3·70	and under	4·7963
C	,,	,,	,,	3·50	,,	3·70
D	,,	,,	,,	3·00	,,	3·50
E	,,	,,	,,	2·50	,,	3·00
F	,,	,,	,,	2·00	,,	2·50
G	,,	,,	—	—	under	2·00

Therefore each liquid will isolate the stones in its own group by compelling them to float on its surface ; commencing with the heaviest and giving to the groups the same letters as the liquids, it is seen that—

Group A.—Isolates gems with a specific gravity of 4·7963 and over 4·70 ; in this group is placed zircon, with a specific gravity of from 4·70 to 4·88.

Group B.—Stones whose specific gravity lies between 3·70 and under 4·7963.

Garnets, many varieties.	See Group D below.		
Almandine . . .	4·11	and occasionally to	4·25
Ruby	4·073	,,	4·080
Sapphire	4·049	,,	4·060
Corundum	3·90	,,	4·16
Cape Ruby. . . .	3·861		
Demantoid. . . .	3·815		
Staurolite	3·735		
Malachite	3·710	and occasionally to	3·996

Group C.—Stones whose specific gravity lies between 3·50 and under 3·70.

Pyrope (average) . .	3·682		
Chrysoberyl . . .	3·689	and occasionally to	3·752
Spinel	3·614	,,	3·654
Kyanite	3·609	,,	3·688
Hessonite	3·603	,,	3·651
Diamond	3·502	,,	3·564
Topaz	3·500	,,	3·520

Group D.—Stones whose specific gravity lies between 3 and under 3·50.

Rhodonite	3·413	and occasionally to	3·617
Garnets.	3·400	,,	4·500
Epidote	3·360	,,	3·480

Sphene	3·348	and occasionally to	3·420
Idocrase	3·346	„	3·410
Olivine	3·334	„	3·368
Chrysolite	3·316	„	3·528
Jade	3·300	„	3·381
Jadeite	3·299		
Axinite	3·295		
Dioptase	3·289		
Diopside	2·279		
Tourmaline (yellow)	3·210		
Andalusite	3·204		
Apatite	3·190		
Tourmaline (Blue and Violet)	3·160		
Tourmaline (Green)	3·148		
„ (Red)	3·100		
Spodumene	3·130	and occasionally to	3·200
Euclase	3·090		
Fluorspar	3·031	and occasionally to	3·200
Tourmaline (Colourless)	3·029		
Tourmaline (Blush Rose)	3·024		
Tourmaline (Black)	3·024	and occasionally to	3·300
Nephrite	3·019		

Group E.—Stones whose specific gravity lies between 2·50 and under 3·000.

Phenakite	2·965		
Turquoise	2·800		
Beryl	2·709	and occasionally to	2·81
Aquamarine	2·701	„	2·80
Labradorite	2·700		
Emerald	2·690		
Quartz	2·670		
Chrysoprase	2·670		
Jasper	2·668		
Amethyst	2·661		

Hornstone	2·658
Citrine	2·658
Cordierite	2·641
Agate	2·610
Chalcedony	2·598 and occasionally to 2·610
Adularia	2·567
Rock-crystal	2·521 and occasionally to 2·795

Group F.—Stones whose specific gravity lies between 2·00 and under 2·50.

Haüynite	2·470 and occasionally to 2·491
Lapis lazuli	2·461
Moldavite	2·354
Opal	2·160 {and according to variety to} 2·283
„ (Fire Opal)	2·210 (average)

Group G.—Stones whose specific gravity is under 2·00.

Jet	1·348
Amber	1·000

(See also list of stones, arranged in their respective colours, in Chapter XII.)

In many of these cases the specific gravity varies from ·11 to ·20, but the above are the average figures obtained from a number of samples specially and separately weighed. In some instances this difference may cause a slight overlapping of the groups, as in group C, where the chrysoberyl may weigh from 3·689 to 3·752, thus bringing the heavier varieties of the stone into group B, but in all cases where overlapping occurs, the colour, form, and the self-evident character of the stone are in themselves sufficient for classification, the specific gravity proving genuineness. This is especially appreciated when

it is remembered that so far science has been unable (except in very rare instances of no importance) to manufacture any stone of the same colour as the genuine and at the same time of the same specific gravity. Either the colour and characteristics suffer in obtaining the required weight or density, or if the colour and other properties of an artificial stone are made closely to resemble the real, then the specific gravity is so greatly different, either more or less, as at once to stamp the jewel as false. In the very few exceptions where chemically-made gems even approach the real in hardness, colour, specific gravity, &c., they cost so much to obtain and the difficulties of production are so great that they become mere chemical curiosities, far more costly than the real gems. Further, they are so much subject to chemical action, and are so susceptible to their surroundings, that their purity and stability cannot be maintained for long even if kept airtight; consequently these ultra-perfect "imitations" are of no commercial value whatever as jewels, even though they may successfully withstand two or three tests.

CHAPTER IX.

PHYSICAL PROPERTIES.

G—Heat.

Another method of isolating certain stones is by the action of heat-rays. Remembering our lessons in physics we recall that just as light-rays may be refracted, absorbed, or reflected, according to the media through which they are caused to pass, so do heat-rays possess similar properties. Therefore, if heat-rays are projected through precious stones, or brought to bear on them in some other manner than by simple projection, they will be refracted, absorbed, or reflected by the stones in the same manner as if they were light-rays, and just as certain stones allow light to pass through their substance, whilst others are opaque, so do some stones offer no resistance to the passage of heat-rays, but allow them free movement through the substance, whilst, in other cases, no passage of heat is possible, the stones being as opaque to heat as to light. Indeed, the properties of light and heat are in many ways identical, though the test by heat must in all cases give place to that by light, which latter is by far of the greater importance in the judging and isolation of precious stones. It will readily be understood that in the spectrum the outer or extreme light-rays at each side are more or less bent or diverted, but those nearest the

centre are comparatively straight, so that, as before remarked, these central rays are taken as being the standard of light-value. This divergence or refraction is greater in some stones than in others, and to it the diamond, as an example, owes its chief charm. In just such manner do certain stones refract, absorb, or reflect heat; thus amber, gypsum, and the like, are practically opaque to heat-rays, in contrast with those of the nature of fluor-spar, rock-salt, &c., which are receptive. Heat passes through these as easily as does light through a diamond, such stones being classed as diathermal (to heat through). So that all diathermal stones are easily permeable by radiant heat, which passes through them exactly as does light through transparent bodies.

Others, again, are both single and double refracting to heat-rays, and it is interesting to note the heat-penetrating value as compared with the refractive indexes of the stone. In the following table will be found the refractive indexes of a selection of single and double refractive stones, the figures for "Light" being taken from a standard list. The second column shows the refractive power of heat, applied to the actual stones, and consisting of a fine pencil blowpipe-flame, one line (the one twelfth part of an inch) in length in each case. This list must be taken as approximate, since in many instances the test has been made on one stone only, without possibility of obtaining an average; and as stones vary considerably, the figures may be raised or lowered slightly, or perhaps even changed in class, because in some stones the least stain or impurity may cause the heat effects to be altered greatly in their

character, and even to become singly or doubly refracting, opaque or transparent, to heat-rays, according to the nature of the impurity or to some slight change in the crystalline structure, and so on.

Selection of Singly refracting stones.	*Indexes of Rays of*	
LIGHT.	HEAT.	
Fluorspar . . .	1·436 . . .	4·10 varies
Opal	1·479 . . .	2·10 ,,
Spinel.	1·726 . . .	1·00
Almandine . . .	1·764 . . .	1·00
Diamond. . . .	2·431 . . .	6·11 double

Selection of Doubly refracting stones.	*Indexes of Rays of*	
LIGHT.	HEAT.	
Quartz . . .	1·545 . . .	4·7 single and double
Beryl . . .	1·575 . . .	1·0 varies considerably
Topaz . . .	1·635 . . .	4·1 ,, ,,
Chrysoberyl .	1·765 . . .	1·1 ,, ,,
Ruby . . .	1·949 . . .	5·1 single and double

The tourmaline has a light-refractive index of 1·63, with a heat index of none, being to heat-rays completely opaque.

The refractive index of gypsum is 1·54, but heat none, being opaque.

The refractive index of amber is 1·51, but heat none, being opaque.

In some of the specimens the gypsum showed a heat-penetration index of 0·001, and amber of 0·056, but mostly not within the third point. In all cases the heat-penetration and refraction were shown by electric recorders. These figures are the average of those obtained from tests made in some cases on several stones of the same kind, and also on isolated specimens. Not only

does the power of the stone to conduct heat vary in different stones of the same kind or variety, as already explained, but there is seen a remarkable difference in value, according to the spot on which the heat is applied, so that on one stone there is often seen a conductivity varying between 0·15 to 4·70.

This is owing to the differences of expansion due to the temporary disturbance of its crystalline structure, brought about by the applied heat. This will be evident when heat is applied on the axes of the crystal, on their faces, angles, lines of symmetry, etc., etc., each one of which gives different results, not only as to value in conductivity, but a result which varies in a curious degree, out of all proportion to the heat applied. In many cases a slight diminution in applied heat gives a greater conductivity, whilst in others a slight rise in the temperature of the heat destroys its conductivity altogether, and renders the stone quite opaque to heat-rays.

This anomaly is due entirely to the alteration of crystalline structure, which, in the one case, is so changed by the diminution in heat as to cause the crystals to be so placed that they become diathermal, or transparent to heat-rays ; whilst, in the other instance, the crystals which so arrange themselves as to be diathermal are, by a slightly increased temperature, somewhat displaced, and reflect, or otherwise oppose the direct passage of heat-rays, which, at the lower temperature, obtained free passage.

Thus certain stones become both opaque and diathermal, and as the heat is caused to vary, so do they show the complete gamut between the two extremes of total opacity and complete transparency to heat-rays.

For the purpose under consideration, the temperature of the pencil of heat applied to the stones in their several portions was kept constant. It will be seen, therefore, that no great reliance can be placed on the heat test as applied to precious stones.

CHAPTER X.

PHYSICAL PROPERTIES.

H—Magnetic and Electric Influences.

The word "electricity" is derived from the Greek "elektron," which was the name for amber, a mineralised resin of extinct pine-trees. It was well-known to the people of pre-historic times; later to the early Egyptians, and, at a still later date, we have recorded how Thales—the Greek philosopher, who lived about the close of the 7th Century B.C., and was one of the "seven wise men"—discovered the peculiar property which we call "electricity" by rubbing dry silk on amber.

Many stones are capable of exhibiting the same phenomenon, not only by friction, as in Thales's experiment, but also under the influence of light, heat, magnetism, chemical action, pressure, etc., and of holding or retaining this induced or added power for a long or short period, according to conditions and environment.

If a small pith ball is suspended from a non-conducting support, it forms a simple and ready means of testing the electricity in a stone. According to whether the ball is repelled or attracted, so is the electricity in the stone made evident, though the electroscope gives the better results. By either of these methods it will be found that some of the stones are more capable of giving and receiv-

ing charges of electricity than are others; also that some are charged throughout with one kind only, either positive or negative, whilst others have both, becoming polarised electrically, having one portion of their substance negative, the other positive. For instance, amber, as is well known, produces negative electricity under the influence of friction, but in almost all cut stones, other than amber, the electricity produced by the same means is positive, whereas in the *uncut* stones the electricity is negative, with the exception of the diamond, in which the electricity is positive.

When heated, some stones lose their electricity; others develop it, others have it reversed, the positive becoming negative and vice versâ; others again, when heated, become powerfully magnetic and assume strong polarity. When electricity develops under the influence of heat, or is in any way connected with a rising or falling of temperature in a body, it is called "pyro-electricity," from the Greek word "pyros," fire. The phenomenon was first discovered in the tourmaline, and it is observed, speaking broadly, only in those minerals which are hemimorphic, that is, where the crystals have different planes or faces at their two ends, examples of which are seen in such crystals as those of axinite, boracite, smithsonite, topaz, etc., all of which are hemimorphic.

Taking the tourmaline as an example of the pyro-electric minerals, we find that when this is heated to between 50° F. and 300° F. it assumes electric polarity, becoming electrified positively at one end or pole and negatively at the opposite pole. If it is suspended on a silken thread from a glass rod or other non-conducting

support in a similar manner to the pith ball, the tourmaline will be found to have become an excellent magnet. By testing this continually as it cools there will soon be perceived a point which is of extreme delicacy of temperature, where the magnetic properties are almost in abeyance. But as the tourmaline cools yet further, though but a fraction of a degree, the magnetic properties change; the positive pole becomes the negative, the negative having changed to the positive.

It is also interesting to note that if the tourmaline is not warmed so high as to reach a temperature of 50° F., or is heated so strongly as to exceed more than a few degrees above 300° F., then these magnetic properties do not appear, as no polarity is present. This polarity, or the presence of positive and negative electricity in one stone, may be strikingly illustrated in a very simple manner:—If a little sulphur and red-lead, both in fine powder, are shaken up together in a paper or similar bag, the moderate friction of particle against particle electrifies both; one negatively, the other positively. If, then, a little of this now golden-coloured mixture is gently dusted over the surface of the tourmaline or other stone possessing electric polarity, a most interesting change is at once apparent. The red-lead separates itself from the sulphur and adheres to the negative portion of the stone, whilst the separated sulphur is at once attracted to the positive end, so that the golden-coloured mixture becomes slowly transformed into its two separate components—the brilliant yellow sulphur, and the equally brilliant red-lead. These particles form in lines and waves around the respective poles in beautiful symmetry, their positions

corresponding with the directions of the lines of magnetic force, exactly as will iron filings round the two poles of a magnet.

From this it will clearly be seen how simple a matter it is to isolate the topaz, tourmaline, and all the pyro-electric stones from the non-pyro-electric, for science has not as yet been able to give to spurious stones these same electric properties, however excellent some imitations may be in other respects. Further, almost all minerals lose their electricity rapidly on exposure to atmospheric influences, even to dry air ; the diamond retains it somewhat longer than most stones, though the sapphire, topaz, and a few others retain it almost as long again as the diamond, and these electric properties are some of the tests which are used in the examination of precious stones.

Those stones which show electricity on the application of pressure are such as the fluorspar, calcite, and topaz.

With regard to magnetism, the actual cause of this is not yet known with certainty. It is, of course, a self-evident fact that the magnetic iron ore, which is a form of peroxide, commonly known as magnetite, or lodestone, has the power of attracting a magnet when swinging free, or of being attracted by a magnet, to account for which many plausible reasons have been advanced. Perhaps the most reasonable and acceptable of these is that this material contains molecules which have half their substance positively and the other half negatively magnetised.

Substances so composed, of which magnets are an

example, may be made the means of magnetising other substances by friction, without they themselves suffering any loss; but it is not all substances that will respond to the magnet. For instance, common iron pyrites, FeS_2, is unresponsive, whilst the magnetic pyrites, which varies from 5FeS, Fe_2S_3, to 6FeS, Fe_2S_3, and is a sulphide of iron, is responsive both positively and negatively. Bismuth and antimony also are inactive, whilst almost all minerals containing even a small percentage of iron will deflect the magnetic needle, at least under the influence of heat. So that from the lodestone—the most powerfully magnetic mineral known—to those minerals possessing no magnetic action whatever, we have a long, graduated scale, in which many of the precious stones appear, those containing iron in their composition being more or less responsive, as already mentioned, and that either in their normal state, or when heated, and always to an extent depending on the quantity or percentage of iron they contain.

In this case, also, science has not as yet been able to introduce into an artificial stone the requisite quantity of iron to bring it the same analytically as the gem it is supposed to represent, without completely spoiling the colour. So that the behaviour of a stone in the presence of a magnet, to the degree to which it should or should not respond, is one of the important tests of a genuine stone.

CHAPTER XI.

THE CUTTING OF PRECIOUS STONES.

As existing in a state of nature precious stones do not, as a rule, exhibit any of those beautiful and wonderful properties which cause them to be so admired and sought after as to become of great intrinsic value, for their surfaces have become clouded by innumerable fine cuts or abrasions, because of the thousands of years during which they have been under pressure, or tumbled about in rivers, or subjected to the incessant friction caused by surrounding substances. All this occurring above and under ground has given them an appearance altogether different to that which follows cutting and polishing, Further, the shape of the stone becomes altered by the same means, and just as Michael Angelo's figure was already in the marble, as he facetiously said, and all he had to do was to chip off what he did not require till he came to it, so is the same process of cutting and polishing necessary to give to the precious stones their full value, and it is the manner in which these delicate and difficult operations are performed that is now under consideration. Just as experience and skill are essential to the obtaining of a perfect figure from the block of marble, so must the cutting and polishing of a precious stone call for the greatest dexterity of which a workman is capable, experience and

skill so great as to be found only in the expert, for in stones of great value even a slight mistake in the shaping and cutting would probably not only be wasteful of the precious material, but would utterly spoil its beauty, causing incalculable loss, and destroying altogether the refrangibility, lustre and colour of the stone, thus rendering it liable to easy fracture : in every sense converting what would have been a rare and magnificent jewel to a comparatively valueless specimen.

One of the chief services rendered by precious stones is that they may be employed as objects of adornment, therefore, the stone must be cut of such a shape as will allow of its being set without falling out of its fastening —not too shallow or thin, to make it unserviceable and liable to fracture, and in the case of a transparent stone, not too deep for the light to penetrate, or much colour and beauty will be lost. Again, very few stones are flawless, and the position in which the flaw or flaws appear will, to a great extent, regulate the shape of the stones, for there are some positions in which a slight flaw would be of small detriment, because they would take little or no reflection, whilst in others, where the reflections go back and forth from facet to facet throughout the stone, a flaw would be magnified times without number, and the value of the stone greatly reduced. It is therefore essential that a flaw should be removed whenever possible, but, when this is not practicable, the expert will cut the stone into such a shape as will bring the defect into the least important part of the finished gem, or probably sacrifice the size and weight of the original stone by cutting it in two or more pieces of such a shape that the cutting and

polishing will obliterate the defective portions. Such a method was adopted with the great Cullinan diamond, as described in Chapter IV. From this remarkable diamond a great number of magnificent stones were obtained, the two chief being the largest and heaviest at present known. Some idea of the size of the original stone may be gathered from the fact that the traditional Indian diamond, the "Great Mogul," is said to have weighed 280 carats. This stone, however, is lost, and some experts believe that it was divided, part of it forming the present famous Koh-i-nûr; at any rate, all trace of the Great Mogul ceased with the looting of Delhi in 1739. The Koh-i-nûr weighs a little over 106 carats; before cutting it weighed a shade over 186; the Cullinan, in the same state, weighed nearly 3254 carats. This massive diamond was cut into about 200 stones, the largest, now placed in "The Royal Sceptre with the Cross," weighing 516½ carats, the second, now placed under the historic ruby in "The Imperial State Crown," weighing 309$\frac{3}{16}$ths carats. These two diamonds are now called "The Stars of Africa." Both these stones, but especially the larger, completely overshadow the notorious Koh-i-nûr, and notwithstanding the flaw which appeared in the original stone, every one of the resulting pieces, irrespective of weight, is without the slightest blemish and of the finest colour ever known, for the great South African diamond is of a quality never even approached by any existing stone, being ideally perfect.

It requires a somewhat elaborate explanation to make clear the various styles of cut without illustrations. They are usually divided into two groups, with curved,

ERRATUM.

Page 64, line 20, *for* "309$\frac{9}{16}$ths Carats,"
read "309$\frac{8}{16}$ths Carats."

and with flat or plane surfaces. Of the first, the curved surfaces, opaque and translucent stones, such as the moon-stone, cat's-eye, etc., are mostly cut *en cabochon*, that is, dome-shaped or semi-circular at the top, flat on the underside, and when the garnet is so cut it is called a carbuncle. In strongly coloured stones, while the upper surface is semi-circular like the cabochon, the under surface is more or less deeply concave, sometimes following the curve of the upper surface, the thickness of the stone being in that case almost parallel throughout. This is called the "hollow" cabochon. Other stones are cut so that the upper surface is dome-shaped like the last two, but the lower is more or less convex, though not so deep as to make the stone spherical. This is called the "double" cabochon.

A further variety of cutting is known as the *goutte de suif*, or the "tallow-drop," which takes the form of a somewhat flattened or long-focus double-convex lens. The more complicated varieties of cut are those appearing in the second group, or those with plane surfaces. A very old form is the "rose" or "rosette"; in this the extreme upper centre, called the "crown," or "star," is usually composed of six triangles, the apexes of which are elevated and joined together, forming one point in the centre. From their bases descend a further series of triangles, the bases and apexes of which are formed by the bases and lower angles of the upper series. This lower belt is called the "teeth," under which the surface or base of the stone is usually flat, but sometimes partakes of a similar shape to the upper surface, though somewhat modified in form.

Another variety is called the "table cut," and is used for coloured stones. It has a flat top or "table" of a square or other shape, the edges of which slope outwards and form the "bezils" or that extended portion by which the stone is held in its setting. It will thus be seen that the outside of the stone is of the same shape as that of the "table," but larger, so that from every portion of the "table" the surface extends downwards, sloping outwards to the extreme size of the stone, the underside sloping downwards and inwards to a small and flat base, the whole, in section, being not unlike the section of a "pegtop."

A modification of this is known as the "step" cut, sometimes also called the "trap." Briefly, the difference between this and the last is that whereas the table has usually one bevel on the upper and lower surfaces, the trap has one or more steps in the sloping parts, hence its name.

The most common of all, and usually applied only to the diamond, is the "brilliant" cut. This is somewhat complicated, and requires detailed description. In section, the shape is substantially that of a pegtop with a flat "table" top and a small flat base. The widest portion is that on which the claws, or other form of setting, hold it securely in position. This portion is called the "girdle," and if we take this as a defining line, that portion which appears above the setting of this girdle, is called the "crown"; the portion below the girdle is called the "culasse," or less commonly the "pavilion." Commencing with the girdle upwards, we have eight "cross facets" in four pairs, a pair on each

side ; each pair having their apexes together, meeting on the four extremities of two lines drawn laterally at right angles through the stone. It will, therefore, be seen that one side of each triangle coincides with the girdle, and as their bases do not meet, these spaces are occupied by eight small triangles, called "skill facets," each of which has, as its base, the girdle, and the outer of its sides coincides with the base of the adjoining "cross facet." The two inner sides of each pair of skill facets form the half of a diamond or lozenge-shaped facet, called a "quoin," of which there are four. The inner or upper half of each of these four quoins forms the bases of two triangles, one at each side, making eight in all, which are called "star facets," and the inner lines of these eight star facets form the boundary of the top of the stone, called the "table." The inner lines also of the star facets immediately below the table and those of the cross facets immediately above the girdle form four "templets," or "bezils." We thus have above the girdle, thirty-three facets : 8 cross, 8 skill, 4 quoin, 8 star, 1 table, and 4 templets.

Reversing the stone and again commencing at the girdle, we have eight "skill facets," sometimes called the lower skill facets, the bases of which are on the girdle, their outer sides forming the bases of eight cross facets, the apexes of which meet on the extremities of the horizontal line, as in those above the girdle. If the basal lines of these cross facets, where they join the sides of the skill facets, are extended to the peak, or narrow end of the stone, these lines, together with the sides of the cross facets, will form four five-sided facets,

called the "pavilions"; the spaces between these four pavilions have their ends nearest the girdle formed by the inner sides of the skill facets, and of these spaces, there will, of course, be four, which also are five-sided figures, and are called "quoins," so that there are eight five-sided facets—four large and four narrow—their bases forming a square, with a small portion of each corner cut away; the bases of the broader pavilions form the four sides, whilst the bases of the four narrower quoins cut off the corners of the square, and this flat portion, bounded by the eight bases, is called the "culet," but more commonly "collet." So that below the girdle, we find twenty-five facets: 8 cross, 8 skill, 4 pavilion, 4 quoin, and 1 collet.

These, with the 33 of the crown, make 58, which is the usual number of facets in a brilliant, though this varies with the character, quality, and size of the diamond. For instance, though this number is considered the best for normal stones, specially large ones often have more, otherwise there is danger of their appearing dull, and it requires a vast amount of skill and experience to decide upon the particular number and size of the facets that will best display the fire and brilliance of a large stone, for it is obvious that if, after months of cutting and polishing, it is found that a greater or smaller number of facets ought to have been allowed, the error cannot be retrieved without considerable loss, and probable ruin to the stone. In the case of the Cullinan diamonds, the two largest of which are called the Stars of Africa, 74 facets were cut in the largest portion, while in the next largest the experts

decided to make 66, and, as already pointed out, these stones are, up to the present time, the most magnificent in fire, beauty and purity ever discovered.

The positions and angles of the facets, as well as the number, are of supreme importance, and diamond cutters —even though they have rules regulating these matters, according to the weight and size of the stone—must exercise the greatest care and exactitude, for their decision once made is practically unalterable.

CHAPTER XII.

IMITATIONS, AND SOME OF THE TESTS, OF PRECIOUS STONES.

We now arrive at the point where it is necessary to discuss the manufacture and re-formation of precious stones, and also to consider a few of the tests which may be applied to *all* stones. These are given here in order to save needless repetition ; the tests which are specially applicable to individual stones will more properly be found under the description of the stone referred to, so that the present chapter will be devoted chiefly to generalities.

With regard to diamonds, the manufacture of these has not as yet been very successful. As will be seen on reference to Chapter II., on "the Origin of Precious Stones," it is generally admitted that these beautiful and valuable minerals are caused by chemically-charged water and occasionally, though not always, high temperature, but invariably beautified and brought to the condition in which they are obtained by the action of weight and pressure, extending unbroken through perhaps ages of time.

In these circumstances, science, though able to give

chemical properties and pressure, cannot, of course, maintain these continuously for "ages," therefore the chemist must manufacture the jewels in such manner that he may soon see the results of his labours, and though real diamonds may be made, and with comparative ease, from boron in the amorphous or pure state along with aluminium, fused in a crucible at a high temperature, these diamonds are but microscopic, nor can a number of them be fused, or in any other way converted into a large single stone, so that imitation stones, to be of any service must be made of a good clear glass. The glass for this purpose is usually composed of 53·70 per cent. of red lead, 38·48 per cent. of pure quartz in fine powder, preferably water-ground, and 7·82 per cent. of carbonate of potash, the whole coloured when necessary with metallic oxides of a similar nature to the constituents of the natural stones imitated. But for colourless diamonds, the glass requires no such addition to tint it. From the formula given is made the material known as "strass," or "paste," and stones made of it are mostly exhibited under and amongst brilliant artificial lights. The mere fact that they are sold cheaply is *primâ facie* proof that the stones are glass, for it is evident that a diamond, the commercial value of which might be £50 or more, cannot be purchased for a few shillings and be genuine. So long as this is understood and the stone is sold for the few shillings, no harm is done ; but to offer it as a genuine stone and at the price of a genuine stone, would amount to fraud, and be punishable accordingly. Some of these "paste," or "white stones," as they are called in the trade, are cut and polished exactly like a diamond, and

with such success as occasionally to deceive all but experts. Such imitations are costly, though, of course, not approaching the value of the real stones ; it being no uncommon thing for valuable jewels to be duplicated in paste, whilst the originals are kept in the strong room of a bank or safe-deposit.

In all cases, however, a hard file will abraid the surface of the false stone. In chapter VII. we found that quartz is in the seventh degree of hardness, and an ordinary file is but a shade harder than this, so that almost all stones higher than No. 7 are unaffected by a file unless it is used roughly, so as to break a sharp edge. In order to prepare artificial diamonds and other stones for the file and various tests, they are often what is called "converted" into "doublets" or "triplets." These are made as follows : the body of the glass is of paste, and on the "table" (see last chapter), and perhaps on the broader facets, there will be placed a very thin slab of the real stone, attached by cement. In the case of the diamond, the body is clear, but in the coloured imitations the paste portion is made somewhat lighter in shade than the real stone would be, the portion below the girdle being coloured chemically, or mounted in a coloured backing. Such a stone will, of course, stand most tests, for the parts usually tested are genuine.

A stone of this nature is called a "doublet," and it is evident that when it is tested on the underside, it will prove too soft, therefore the "triplet" has been introduced. This is exactly on the lines of the doublet, except that the collet and perhaps the pavilions are covered also, so that the girdle, which is generally en-

cased by the mounting, is the only surface-portion of paste. In other cases the whole of the crown is genuine, whilst often both the upper and lower portions are solid and genuine, the saving being effected by using a paste centre at the girdle, covered by the mounting. Such a stone as this last mentioned is often difficult to detect without using severe tests and desperate means, e.g. :— (*a*) by its crystalline structure (see Chapter III.) ; (*b*) by the cleavage planes (see Chapter IV.) ; (*c*) by the polariscope (see Chapter V.) ; (*d*) by the dichroscope (see Chapter VI.) ; (*e*) by specific gravity (see Chapter VIII.) ; (*f*) cutting off the mounting, and examining the girdle ; (*g*) soaking the stone for a minute or so in a mixture said to have been originally discovered by M. D. Rothschild, and composed of hydrofluoric acid and ammonia ; this will not answer for all stones, but is safe to use for the diamond and a few others. Should the jewel be glass, it will be etched, if not completely destroyed, but if genuine, no change will be apparent ; (*h*) soaking the diamond for a few minutes in warm or cold water, in alcohol, in chloroform, or in all these in turn, when, if a doublet, or triplet, it will tumble to pieces where joined together by the cement, which will have been dissolved. It is, however, seldom necessary to test so far, for an examination under the microscope, even with low power, is usually sufficient to detect in the glass the air-bubbles which are almost inseparable from glass-mixtures, though they do not detract from the physical properties of the glass. The higher powers of the same instrument will almost always define the junction and the layer or layers of cement, no matter

how delicate a film may have been used. Any one of these tests is sufficient to isolate a false stone.

Some of the softer genuine stones may be fused together with splinters, dust, and cuttings of the same stones, and of this product is formed a larger stone, which, though manufactured, is essentially perfectly real, possessing exactly the same properties as a naturally formed stone. Many such stones are obtained as large as an ordinary pin's head, and are much used commercially for cluster-work in rings, brooches, for watch-jewels, scarf-pins, and the like, and are capable of being cut and polished exactly like an original stone. This is a means of using up to great advantage the lapidary's dust, and though these products are real stones, perhaps a little more enriched in colour chemically, they are much cheaper than a natural stone of the same size and weight.

Some spurious stones have their colour improved by heat, by being tinged on the outside, by being tinted throughout with a fixed colour and placed in a clear setting; others, again, have a setting of a different hue, so that the reflection of this shall give additional colour and fire to the stone. For instance, glass diamonds are often set with the whole of the portion below the girdle hidden, this part of the stone being silvered like a mirror. Others are set open, being held at the girdle only, the portion covered by the setting being silvered. Other glass imitations, such as the opal, have a tolerably good representation of the "fiery" opal given to them by the admixture, in the glass, of a little oxide of tin, which makes it somewhat opalescent, and in the setting is

placed a backing of red, gold, copper, or fiery-coloured tinsel, whilst the glass itself, at the back, is painted very thinly with a paint composed of well washed and dried fish-scales, reduced to an impalpable powder, mixed with a little pure, refined mastic, or other colourless varnish. This gives a good imitation of phosphorescence, as well as a slight pearliness, whilst the tinsel, seen through the paint and the curious milkiness of the glass, gives good "fire."

A knowledge of the colours natural to precious stones and to jewels generally is of great service in their rough classification for testing, even though some stones are found in a variety of colours. An alphabetical list of the most useful is here appended, together with their average specific gravities and hardness. (See also Chapter VII. on "Hardness," and Chapter VIII. on "Specific Gravity.")

White or Colourless Stones.

	Hardness. (See Chapter VII.)	*Specific Gravity.* (See Chapter VIII.)
Beryl	7½	2·709–2·81
Corundum	9	3·90–4·16
Diamond	10	3·502–3·564
Jade	7	3·300–3·381
Opal	5½–6½	2·160–2·283
Phenakite	7½	2·965
Quartz	7	2·670
Rock-crystal	7	2·521–2·795
Sapphire	9	4·049–4·060
Spinel	8	3·614–3·654
Topaz	8	3·500–3·520
Tourmaline	7½	3·029
Zircon	7½	4·700–4·880

Yellow Stones.

	Hardness. (See Chapter VII.)	*Specific Gravity.* (See Chapter VIII.)
Amber	2½	1·000
Beryl	7⅝	2·709–2·810
Chrysoberyl	8½	3·689–3·752
Chrysolite	6–7	3·316–3·528
Corundum (the yellow variety known as "Oriental Topaz" [not "Topaz"], see below)	9	3·90–4·16
Diamond	10	3·502–3·564
Garnets (various)	6½–7½	3·4–4·5
Hyacinth (a form of Zircon)	7½	4·7–4·88
Quartz (Citrine)	7	2·658
Sapphire	9	4·049–4·060
Spinel	8	3·614–3·654
Topaz (for "Oriental Topaz," see above)	8	3·500–3·520
Tourmaline	7¼	3·210

Brown and Flame-Coloured Stones.

	Hardness. (See Chapter VII.)	*Specific Gravity.* (See Chapter VIII.)
Andalusite	7½	3·204
Diamond	10	3·502–3·564
Garnets (various)	6½–7½	3·40–4·50
Hyacinth (a form of Zircon), see below	7½	4·70–4·88
Quartz (smoke coloured)	7	2·670
Tourmaline	7¼	3·100
Zircon (Hyacinth)	7½	4·70–4·88

Red and Rose-Coloured Stones.

	Hardness. (See Chapter VII.)	*Specific Gravity.* (See Chapter VIII.)
Carnelian (a variety of Chalcedony)	6½	2·598–2·610
Diamond	10	3·502–3·564
Deep Red Garnet	7½	3·40–4·50

	Hardness. (See Chapter VII.)	*Specific Gravity.* (See Chapter VIII.)
Jasper	7	2·668
Opal (the "Fire Opal")	5½–6½	2·21 (average)
Ruby	9	4·073–4·080
Rhodonite	5½–6½	3·413–3·617
Sapphire	9	4·049–4·060
Spinel Ruby	8	3·614–3·654
Topaz	8	3·500–3·520
Tourmaline	7¼	3·024
Zircon	7½	4·70–4·88

Pink Stones.

	Hardness. (See Chapter VII.)	*Specific Gravity.* (See Chapter VIII.)
Beryl	7¾	2·709–2·810
Diamond	10	3·502–3·564
Ruby	9	4·073–4·080
Spinel	8	3·614–3·654
Topaz ("burnt" or "pinked"), see Chapter XIV., page 92	8	3·500–3·520
Tourmaline	7¼	3·024

Blue Stones.

	Hardness. (See Chapter VII.)	*Specific Gravity.* (See Chapter VIII.)
Beryl	7¾	2·709–2·810
Diamond	10	3·502–3·564
Dichorite (Water Sapphire)	7–7½	4·049–4·060
Disthene (Kyanite)	5–7	3·609–3·688
Iolite (Cordierite)	7¼	2·641
Lapis lazuli	5½	2·461
Sapphire	9	4·049–4·060
Topaz	8	3·500–3·520
Tourmaline	7¼	3·160
Turquoise	6	2·800

Green Stones.

	Hardness. (See Chapter VII.)	*Specific Gravity.* (See Chapter VIII.)
Aquamarine	7¾	2·701–2·800
Chrysoberyl	8½	3·689–3·752
Chrysolite	6–7	3·316–3·528
Chrysoprase (Quartz)	7	2·670
Diamond	10	3·502–3·564
Dioptase	5	3·289
Emerald and Oriental Emerald	7¾	2·690
Euclase	7½	3·090
Garnet (see also Red Garnet)	6½–7½	3·400–4·500
Heliotrope (Chalcedony)	6½	2·598–2·610
Hiddenite (a variety of Spodumene)	6½–7	3·130–3·200
Jade	7	3·300–3·381
Jadeite	7	3·299
Malachite	3½	3·710–3·996
Peridot (a variety of Chrysolite)	6–7	3·316–3·528
Plasma (a variety of Chalcedony)	6½	2·598–2·610
Quartz	7	2·670
Sapphire	9	4·049–4·060
Topaz	8	3·500–3·520
Tourmaline	7¼	3·148

Violet Stones.

	Hardness. (See Chapter VII.)	*Specific Gravity.* (See Chapter VIII.)
Amethyst	7	2·661
Diamond	10	3·502–3·564
Quartz (Amethyst)	7	2·670
Sapphire	9	4·049–4·060
Spinel	8	3·614–3·654
Tourmaline	7¼	3·160

Chatoyant Stones.

These stones are easily recognisable by their play of colour. (See Chapter XIV.)

Black Stones.

	Hardness. (See Chapter VII.)	*Specific Gravity.* (See Chapter VIII.)
Diamond	10	3·502–3·564
Garnet	$6\frac{1}{2}$–$7\frac{1}{2}$	3·400–4·500
Jet	$3\frac{1}{2}$	1·348
Onyx (a variety of Chalcedony)	$6\frac{1}{2}$	2·598–2·610
Quartz	7	2·670
Tourmaline (not unlike Black Resin in appearance)	$7\frac{1}{4}$	3·024–3·300

CHAPTER XIII.

VARIOUS PRECIOUS STONES.

The Diamond.

To recapitulate certain of the facts respecting the diamond.—This wonderful gem has the distinction amongst precious stones of being unique ; though many are composed of two, three, or but a small number of elements, the diamond is the only stone known consisting of one element, and absolutely nothing else—pure crystallised carbon. Its hardness is proverbial ; not only is it untouched by the action of a hard file, but it occasionally refuses to split when struck with finely tempered steel, which it often causes to break. Such was the case with the South African diamond, for when the knife that was to break it was struck smartly with a steel bar, the first blow broke the blade without affecting the diamond, yet a piece of bort, or diamond dust, splinters, or defective diamonds (all these being called bort), may readily be pulverised in a hard steel mortar with a hard steel pestle.

The diamond is the hardest stone known ; it is also the only stone known which is really combustible. It is of true adamantine lustre, classed by experts as midway between the truly metallic and the purely resinous. In refractive power and dispersion of the coloured rays of

light, called its fire, it stands pre-eminent. It possesses a considerable variety of colour; that regarded as the most perfect and rare is the blue-white colour. Most commonly, however, the colours are clear, with steely-blue casts, pale and neutral-colour yellow, whilst amongst the most expensive and rare are those of green, pale pink, red, and any other variety with strong and decided colour. Although these stones are sold by the carat, there can be no hard and fast rule laid down as to the value of a carat, for this depends on the size, quality, and the purity of the stone. The larger the stone the greater the value per carat, and prices have been known to range from 25*l.* per carat for a small stone to 500*l.* per carat for a large one, whereas the exceptionally large stones possess a value almost beyond estimation.

It often happens that some stones—particularly those from South Africa and Brazil—are tinted when uncut, probably by reason of the action upon them of their matrix, especially if ironstone, or with rolling for ages amongst ironstone in river-beds, which gives them a slight metallic appearance; in each case the cause is suggested by the fact that these tinted stones are usually found in such places, and that the tinting is very thin and on the surface only, so that the cutting and shaping of the stone gets below it to the perfectly clear diamond.

From Pliny and other historians we gather that at various periods considerable superstition has existed with regard to diamonds, such as that if one is powdered it becomes poisonous to a remarkable degree; that gifts of diamonds between lovers—married and unmarried—produce and seal affection; hence the popularity of dia-

monds in betrothal rings. Pretty as is this conceit, there is no doubt about the fact that the gift of diamonds to the object of one's affections does usually produce a feeling of pleasure to both parties, from which it would appear that there is some ground for the belief.

Corundum.

This mineral is a species of crystal, or crystalline alumina—an almost pure anhydrous alumina, Al_2O_3—in many varieties, both of shape and colour. The chief stone is the ruby, considered, when large, to be of even more importance and value than the diamond. There are many other red stones in this group; sapphires, also, are a species of corundum, both the blue and the colourless varieties, as are also the aquamarine, the emerald, the amethyst, the topaz, and others, all of widely differing colour, as well as the star-shaped, or "aster" ruby, called the "ruby" cat's-eye. All these vary more in colour than in their chemical properties. Still another variety, greyish-black and generally associated with hæmatite iron ore, is called emery, and, when ground in different degrees of fineness, is so well known by its general use as a polishing medium as to need no description. It should, however, be mentioned that amongst the more coarsely ground emery it is no uncommon thing to find minute sapphires, taking sapphires in their broad, commercial meaning, as signifying any variety of corundum, except the red and the emery. The surfaces of crystals of corundum are often clouded or dull, whilst its classification of lustre is vitreous. It is double refracting and

has no cleavage. It is found in China, India, Burma, Ceylon, South Africa, America, and in many other places, having a wide distribution.

The Ruby.

In the dichroscope the ruby shows two images, one square of a violet red, the second square being a truer and a paler red. It may be subjected to strong heat, when it changes its colour to a sooty or dirty slate, this varying with the locality in which the stone is found, and the manner in which the heat is applied. But as it cools it becomes paler and greener, till it slowly enrichens; the green first becomes broken, then warmer, redder, and finally assumes its original beautiful blood red. This method of heating is sometimes used as a test, but it is a test which often means the complete ruin of a stone which is not genuine. Another characteristic which, in the eyes of the expert, invariably isolates a real from an artificial ruby is its curious mild brilliance, which as yet has not been reproduced by any scientific method in paste or any other material, but perhaps the safest test of all is the crystalline structure, which identical structure appears in no other stone, though it is possible, by heating alumina coloured with oxide of iron and perhaps also a trace of oxide of chromium to a very high temperature for a considerable time, and then cooling very slowly, to obtain a ruby which is nearly the same in its structure as the real gem; its specific gravity and hardness may perhaps be to standard, and when properly cut, its brilliance would deceive all but an expert. And as in some real

rubies there are found slight hollows corresponding or analogous to the bubbles found in melted glass, it becomes a matter of great difficulty to distinguish the real from the imitation by such tests as hardness, specific gravity, dichroism, and the like, so that in such a case, short of risking the ruin of the stone, ordinary persons are unable to apply any convincing tests. Therefore, only the expert can decide, by his appreciation of the delicate shade of difference in the light of a true ruby and that of an excellent imitation, and by the distribution of the colour, which—however experienced the chemist may be, or with what care the colouring matter may have been incorporated in the mass—has been found impossible of distribution throughout the body of an artificial stone so perfectly and in the same manner and direction as nature herself distributes it in the genuine. This alone, even in the closest imitations, is clear to the eye of the expert, though not to the untrained eye, unless the stone is palpably spurious. To one who is accustomed to the examination of precious stones, however perfect the imitation, it is but necessary to place it beside or amongst one or more real ones for the false to be almost instantly identified, and that with certainty.

The Sapphire.

The Sapphire is not so easy to imitate, as its hardness exceeds that of the ruby, and imitations containing its known constituents, or of glass, are invariably softer than the natural stone. As before remarked, almost any form of corundum other than red is, broadly, called sap-

phire, but giving them their strictly correct designations, we have the olivine corundum, called "chrysolite" (oriental), which is harder than the ordinary or "noble" chrysolite, sometimes called the "peridot." The various yellow varieties of corundum take the name of the "oriental topaz," which, like most, if not all, the corundum varieties, is harder than the gem which bears the same name, minus the prefix "oriental." Then we have the "amethyst" sapphire, which varies from a red to a blue purple, being richer in colour than the ordinary amethyst, which is a form of violet-coloured quartz, but the corundum variety, which, like its companions, is called the "oriental" amethyst, is both rarer and more precious. A very rare and extremely beautiful green variety is called the oriental emerald. The oriental jacinth, or hyacinth, is a brown-red corundum, which is more stable than the ordinary hyacinth, this latter being a form of zircon; it changes colour on exposure to light, which colour is not restored by subsequent retention in darkness.

The blue sapphire is of all shades of blue, from cornflower blue to the very palest tints of this colour, all the gradations from light to dark purple blues, and, in fact, so many shades of tone and colour that they become almost as numerous as the stones. These stones are usually found in similar situations to those which produce the ruby, and often along with them. The lighter colours are usually called females, or feminine stones, whilst the darker ones are called masculine stones. Some of these dark ones are so deep as to be almost black, when they are called "ink" sapphires, and if inclining to

blue, "indigo" sapphires, in contradistinction to which the palest of the stones are called "water" sapphires. The colouring matter is not always even, but is often spread over the substance of the stone in scabs or "splotches," which rather favours imitation, and, where this unevenness occurs, it may be necessary to cut or divide the stone, or so to arrange the form of it that the finished stone shall be equally blue throughout.

In some cases, however, the sapphire may owe its beauty to the presence of two, three or more colours in separate strata appearing in one stone; such as a portion being a green-blue, another a cornflower blue, another perfectly colourless; another a pale sky blue, another yellow, each perfectly distinct, the stone being cut so as to show each colour in its full perfection.

This stone, the sapphire, is hardness No. 9 (see "Hardness" table), and therefore ranks next to the diamond, which makes it a matter of great difficulty to obtain an imitation which is of the same specific gravity and of the same degree of hardness, though this has been done. Such stones are purchasable, but though sold as imitations at comparatively low price, and the buyer may consider them just as good as the real gem, to the experienced eye they are readily detectable.

By heating a sapphire its blue colour slowly fades, to complete transparency in many cases, or at any rate to so pale a tint as to pass for a transparent stone. Valuable as is the sapphire, the diamond is more so, and it follows that if one of these clear or "cleared" sapphires is cut in the "rose" or "brilliant" form—which forms are reserved almost exclusively for the

diamond—such a stone would pass very well as a diamond, and many so cut are sold by unscrupulous people as the more valuable stone, which fraud an expert would, of course, detect.

Sapphires are mentioned by Pliny, and figure largely in the ancient history of China, Egypt, Rome, etc. The Greeks dedicated the sapphire specially to Jupiter, and many of the stones were cut to represent the god; it also figured as one of the chief stones worn by the Jewish High Priest on the breast-plate. Some stones have curious rays of variegated colour, due to their crystalline formation, taking the shape of a star; these are called "asteriated," or "cat's eye" sapphires. Others have curious flashes of light, technically called a "play" of light (as described in Chapter VI. on "Colour"), together with a curious blue opalescence; these are the "girasol." Another interesting variety of this blue sapphire is one known as "chatoyant"; this has a rapidly changing lustre, which seems to undulate between a green-yellow and a luminous blue, with a phosphorescent glow, or fire, something like that seen in the eyes of a cat in the dark, or the steady, burning glow observed when the cat is fascinating a bird—hence its name. This is not the same variety as the "asteriated," or "cat's eye" or "lynx eye" mentioned above.

CHAPTER XIV.

VARIOUS PRECIOUS STONES—*continued.*

The Chrysoberyl.

THERE are certain stones and other minerals which, owing to their possession of numerous microscopically fine cavities, of a globular or tubular shape, have the appearance of "rays" or "stars," and these are called "asteriated." Several of such stones have been discussed already in the last chapter, and in addition to these star-like rays, some of the stones have, running through their substance, one or more streaks, perhaps of asbestos or calcite, some being perfectly clear, whilst others are opalescent. When these streaks pass across the star-like radiations they give the stone the appearance of an eye, the rays forming the iris, the clear, opalescent, or black streak closely resembling the slit in a cat's eye, and when these stones are cut *en cabochon*, that is, dome-shaped (see Chapter XI. on "Cutting"), there is nothing to deflect the light beams back and forth from facet to facet, as in a diamond, so that the light, acting directly on these radiations or masses of globular cavities and on the streak, causes the former to glow like living fire, and the streak appears to vibrate, palpitate,

expand, and contract, exactly like the slit in the eye of a cat.

There are a considerable number of superstitions in connection with these cat's-eye stones, many people regarding them as mascots, or with disfavour, according to their colour. When possessing the favourite hue or "fire" of the wearer, such as the fire of the opal for those born in October, of the ruby for those born in July, etc., these stones are considered to bring nothing but good luck; to ward off accident, danger, and sudden death; to be a charm against being bitten by animals, and to be a protection from poison, the "evil eye," etc. They figured largely, along with other valuable jewels, in the worship of the ancient Egyptians, and have been found in some of the tombs in Egypt. They also appeared on the "systrum," which was a sacred instrument used by the ancient Egyptians in the performance of their religious rites, particularly in their sacrifices to the goddess Isis. This, therefore, may be considered one of their sacred stones, whilst there is some analogy between the cat's-eye stones and the sacred cat of the Egyptians which recurs so often in their hieroglyphics; it is well known that our domestic cat is not descended from the wild cat, but from the celebrated cat of Egypt, where history records its being "domesticated" at least thirteen centuries B.C. From there it was taken throughout Europe, where it appeared at least a century B.C., and was kept as a pet in the homes of the wealthy, though certain writers, speaking of the "mouse-hunters" of the old Romans and Greeks, state that these creatures were not the Egyptian cat, but a carniverous, long-bodied

animal, after the shape of a weasel, called "marten," of the species the "beech" or "common" marten (*mustela foina*), found also in Britain to-day. It is also interesting to note that the various superstitions existing with regard to the different varieties and colours of cats also exist in an identical manner with the corresponding colours of the minerals known as "cat's eye."

Several varieties of cat's-eye have already been described. Another important variety is that of the chrysoberyl called "cymophane." This is composed of glucina, which is glucinum oxide, or beryllia, BeO, of which there is 19·8 per cent., and alumina, or aluminium oxide, Al_2O_3, of which there is 80·2 per cent. It has, therefore, the chemical formula, BeO,Al_2O_3. This stone shows positive electricity when rubbed, and, unlike the sapphires described in the last chapter, which lose their colour when heated, this variety of chrysoberyl shows no change in colour, and any electricity given to it, either by friction or heat, is retained for a long time. When heated in the blow-pipe alone it remains unaltered, that is, it is not fusible, and even with microcosmic salt it requires a considerably long and fierce heat before it yields and fuses, and acids do not act upon it. It crystallises in the 4th (rhombic) system, and its lustre is vitreous.

The cymophane shows a number of varieties, quite as many as the chrysoberyl, of which it is itself a variety, and these go through the gamut of greens, from a pale white green to the stronger green of asparagus, and through both the grey and yellow greens to dark. It is found in Ceylon, Moravia, the Ural Mountains, Brazil,

North America, and elsewhere. The cat's-eye of this is very similar to the quartz cat's-eye, but a comparison will make the difference so clear that they could never be mistaken, apart from the fact that the quartz has a specific gravity considerably lower than the chrysoberyl cat's-eye, which latter is the true cat's-eye, and the one usually understood when allusion is made to the stone without any distinguishing prefix, such as the ruby, sapphire, quartz, etc., cat's eye. It should, however, be mentioned that this stone is referred to when the names Ceylonese and Oriental cat's-eye are given, which names are used in the trade as well as the simple appellation, "cat's eye." One peculiarity of some of these stones is that the "fire" or "glow" is usually altered in colour by the colour of the light under which it is seen, the change of colour being generally the complementary. Thus, a stone which in one light shows red, in another will be green; the "eye" showing blue in one light will become orange in another; whilst the yellow of another stone may show a decided purple or amethyst in a different light.

A good test for this, and indeed most precious stones, is that they conduct heat more quickly than does glass, and with such rapidity that on breathing upon a stone the warmth is conducted instantly, so that, though the stone is dimmed the dimness vanishes at once, whereas with glass the film of moisture fades but slowly in comparison.

The Topaz.

The name topaz is derived from the Greek *topazos*, which is the name of a small island situated in the Gulf

of Arabia, from whence the Romans obtained a mineral which they called topazos and topazion, which mineral to-day is termed chrysolite. The mineral topaz is found in Cornwall and in the British Isles generally ; also in Siberia, India, South America and many other localities, some of the finest stones coming from Saxony, Bohemia, and Brazil, especially the last-named. The cleavage is perfect and parallel to the basal plane. It crystallises in the 4th (rhombic) system ; in lustre it is vitreous ; it is transparent, or ranging from that to translucent ; the streak is white or colourless. Its colour varies very much —some stones are straw-colour, some are grey, white, blue, green, and orange. A very favourite colour is the pink, but in most cases this colour is not natural to the stone, but is the result of " burning," or " pinking " as the process is called technically, which process is to raise the temperature of a yellow stone till the yellow tint turns to a pink of the colour desired. The topaz is harder than quartz, as will be seen on reference to the " Hardness " table, and is composed of a silicate of aluminium, fluorine taking the place of some of the oxygen. Its composition averages 16·25 per cent. of silica, 55·75 per cent. of alumina, or oxide of aluminium, and fluoride of silicium, 28 per cent. Its formula is $[Al\,(F, O\,H)]_2\,Si\,O_4$, or $(Al\,F)_2\,Si\,O_4$. From this it will be understood that the fluorine will be evolved when the stone is fused. It is, however, very difficult to fuse, and alone it is infusible under the blow-pipe, but with microcosmic salt it fuses and evolves fluorine, and the glass of the tube in the open end of which the stone is fixed is bitten with the gas.

Such experiments with the topaz are highly interesting, and if we take a little of the powdered stone and mix with it a small portion of the microcosmic salt, we may apply the usual test for analysing and proving aluminium, thus : a strongly brilliant mass is seen when hot, and if we moisten the powder with nitrate of cobalt and heat again, this time in the inner flame, the mass becomes blue. Other phenomena are seen during the influence of heat. Some stones, as stated, become pink on heating, but if the heating is continued too long, or too strongly, the stone is decoloured. Others, again, suffer no change, and this has led to a slight difference of opinion amongst chemists as to whether the colour is due to inorganic or organic matter. Heating also produces electricity, and the stone, and even splinters of it, will give out a curious phosphorescent light, which is sometimes yellow, sometimes blue, or green. Friction or pressure produces strong electrification ; thus the stones may be electrified by shaking a few together in a bag, or by the tumbling of the powdered stone-grains over each other as they roll down a short inclined plane. The stones are usually found in the primitive rocks, varying somewhat in different localities in their colour ; many of the Brazilian stones, when cut as diamonds, are not unlike them.

In testing, besides those qualities already enumerated, the crystalline structure is specially perfect and unmistakable. It is doubly refractive, whereas spinel and the diamond, which two it closely resembles, are singly refractive. Topaz is readily electrified, and, if perfect at terminals, becomes polarised ; also the commercial

solution of violets, of which a drop only need be taken for test, is turned green by adding to it a few grains of topaz dust, or of a little splinter crushed to fine powder.

The Beryl.

The beryl is a compound of silicates of beryllia and alumina, with the formula $3BeOSiO_2 + Al_2O_3$, $3SiO_2$, or $3BeO,Al_2O_3,6SiO_2$. It differs very little indeed from the emerald, with the exception of its colour. In the ordinary varieties this is somewhat poor, being mostly blue, or a dirty or a greenish yellow; the better kinds, however, possess magnificent colour and variety, such as in the aquamarine, emerald, etc. The cleavage is parallel to the basal plane. Its lustre is sometimes resinous, sometimes vitreous, and it crystallises in the 2nd (hexagonal) system. It occurs in somewhat long, hexagonal prisms, with smooth, truncated planes, and is often found in granite and the silt brought down by rivers from granite, gneiss, and similar rocks. It is found in Great Britain and in many parts of Europe, Asia, and America, in crystals of all sizes, from small to the weight of several tons. The common kinds are too opaque and colourless to be used as gems and are somewhat difficult of fusion under the blowpipe, on the application of which heat some stones lose their colour altogether, others partly; others, which before heating were somewhat transparent, become clouded and opaque; others suffer no change in colour, whilst some are improved. In almost every case a slight fusion is seen on the sharp edges of fractures, which become smooth, lose their sharpness, and have the appearance of partly fused

glass. The hardness varies from $7\frac{1}{4}$ to 8, the crystals being very brittle, breaking with a fracture of great unevenness. The better varieties are transparent, varying from that to translucent, and are called the "noble" beryls. Transparent beryl crystals are used by fortune-tellers as "gazing stones," in which they claim to see visions of future events.

The Emerald.

Considering the particular emerald which is a variety of beryl—although the name emerald in the trade is applied somewhat loosely to any stone which is of the same colour, or approaching the colour of the beryl variety—this emerald only differs chemically from the beryl, just described, in possessing an addition of oxide of chromium. In shape, crystallisation, fracture and hardness, it is the same, and often contains, in addition to the chromium, the further addition of traces of carbonate of lime, magnesia, and occasionally faint traces of hornblende and mica, which evidently result from its intimate association with the granite rock and gneiss, amongst which it is mostly found, the latter rocks being of a slaty nature, in layers or plates, and, like granite, containing mica, pyrites, felspar, quartz, etc.

Emeralds have been known from very early times, and are supposed to have been found first in the mines of ancient Egypt. They were considered amongst the rarest and the most costly of gems, and it was the custom, when conferring lavish honour, to engrave or model emeralds for presentation purposes. Thus we find Pliny describes Ptolemy giving Lucullus, on his landing

at Alexandria, an emerald on which was engraved his portrait. Pliny also relates how the short-sighted Nero watched the fights of gladiators through an eye-glass made of an emerald, and in ancient times, in Rome, Greece, and Egypt, eye-glasses made of emeralds were much valued. Many of these, as well as engraved and carved emeralds, have been discovered in ruins and tombs of those periods.

The copper emerald is rare ; it is a hydrous form of copper silicate, $CuOSiO_2 + H_2O$, of a beautiful emerald green, varying from transparent to translucent. It exhibits double refraction, and is a crystallised mineral, brittle, and showing a green streak. This is less hard than the real emerald, is heavier, deeper in colour, and is usually found in crystals, in cavities of a particular kind of limestone which exists at Altyn-Tübe, a hill in the Altai Mountains, in the Urals, and in North and Central America.

The Tourmaline.

The tourmaline is a most complex substance ; almost every stone obtained has a different composition, some varying but slightly, with mere traces of certain constituents which other stones possess in a perceptible degree. Consequently, it is not possible to give the chemical formula, which might, and possibly would, be found but seldom, even in analyses of many specimens. It will therefore be sufficient to state the average composition, which is :—ferrous oxide, manganous oxide, potash, lime, boracic acid, magnesia, soda, lithia, and water. These form, roughly speaking, 25 per cent. of the bulk, the remainder being oxide of silicon and oxide

of aluminium in about equal parts. It crystallises in the 2nd (hexagonal) system, with difficult cleavage and vitreous lustre.

It will naturally be expected that a substance of such complexity and variety of composition must necessarily have a corresponding variety of colour; thus we find in this, as in the corundum, a wonderful range of tints. The common is the black, which is not used as a gem. Next come the colourless specimens, which are not often cut and polished, whereas all the transparent and coloured varieties are in great demand. To describe adequately their characteristics with relation to light would alone require the space of a complete volume, and the reader is referred to the many excellent works on physics (optics) which are obtainable. This stone is doubly refracting, exhibiting extremely strong dichroism, especially in the blue and the green varieties. It polarises light, and when viewed with the dichroscope shows a remarkable variety of twin colours. It will be remembered that in Hogarth's "Rake's Progress," the youth is too engrossed in the changing wonders of a tourmaline to notice the entrance of the officers come to arrest him.

CHAPTER XV.

VARIOUS PRECIOUS STONES—*continued.*

Zircon.

ZIRCON appears to have been first discovered by Klaproth in 1789, in the form of an earth, and six years later he found that the stone hyacinth contained a similar substance, both having the formula, $ZrSiO_4$, and both having as their colouring agent ferric oxide. There are several methods of obtaining the metallic element, zirconium; it is however with the silicate of zirconium that we have to deal at the moment. This is called zircon, $ZrSiO_4$, or hyacinth when transparent or red, but when smoke-coloured, or colourless, it is the jargoon, or jarcon, and is found in silt and alluvial soils, limestone, gneiss, and various forms of schist, in India, Australia, the Urals, and certain parts of America. It is often combined with and found in juxtaposition to gold and certain varieties of precious stones. The lines of cleavage are parallel to the sides of the prism, and the crystals have an adamantine, or diamond lustre, varying from the completely opaque to the transparent. In some varieties the oxide of uranium is also present in traces. It crystallises in the 3rd (tetragonal) system, with indis-

tinct cleavage. Its specific gravity varies from 4·70 to 4·88, according to the specimen and the locality.

This stone, like some of the others described, has a very wide range of colour, going through reds, browns, greens, yellows, oranges, whites, greys, blues from light to indigo, notwithstanding which it is somewhat difficult to imitate scientifically, though its composition of 33 per cent. of silica with 67 per cent. of zirconia (the oxide of zirconium), is practically all it contains, apart from the colouring matter, such as the metallic oxides of iron, uranium, etc. Its hardness is 7½, consequently it is untouched by a file, and so far, if one or perhaps two of the three qualities of colour, hardness, and specific gravity, are obtained in a chemically made zircon, the third is wanting. Under the blowpipe, zircons are infusible, but the coloured stones when heated strongly become heavier, and as they are contracting, their colour fades, sometimes entirely, which changes are permanent, so that as they possess the adamantine lustre, they are occasionally cut like a diamond, and used as such, though their deficiency in fire and hardness, and their high specific gravity, make them readily distinguishable from the diamond.

On exposure to light the coloured zircon becomes more or less decoloured; especially is this so in sunlight, for when the direct rays of the sun fall upon it, the colours fade, and for a moment or two occasional phosphorescence follows, as is the case when the stone is warmed or heated in a dark room. The stone appears to be very susceptible to brilliant light-rays, and in certain specimens which were split for testing, one half of each being kept excluded from light for purposes of

comparison, it was found that sunshine affected them most; then brilliant acetylene gas, which was more effective still when tinted yellow by being passed through yellow glass. The electric arc was not so effective, but the electric light of the mercury-vapour lamp, though causing little change at the first, after a few hours' exposure rapidly bleached certain of the colours, whilst having no effect on others. Coal gas with incandescent fibre mantle was slightly effective, whilst the coal-gas, burned direct through an ordinary burner, affected very few of the colours, even after twenty-four hours' exposure at a distance of three feet. In all these cases, though the colours were slightly improved by the stones being kept for a time in the dark, they failed to recover their original strength, showing permanent loss of colour.

The Silicates.

The chief of these are the garnets, crystallising in the cubic system, and anhydrous. The garnet is usually in the form of a rhombic dodecahedron, or as a trisoctahedron (called also sometimes an icosatetrahedron), or a mixture of the two, though the stones appear in other cubic forms. In hardness they vary from $6\frac{1}{2}$ to $8\frac{1}{2}$. They average from 40 to about 42 per cent. of silica, the other ingredients being in fairly constant and definite proportions. They are vitreous and resinous in their lustre and of great variety of colour, chiefly amongst reds, purples, violets, greens, yellows and blacks, according to the colouring matter present in their mass. There are many varieties which are named in accordance with one or more of their constituents, the best known being:

(A) The iron-alumina garnet, having the formula $6FeO, 3SiO_2 + 2Al_2O_3, 3SiO_2$. This is the "precious" garnet, or almandine, sometimes called the "Oriental" garnet; these stones are found in Great Britain, India, and South America, and are deep red and transparent, of vitreous lustre. They get up well, but certain varieties are so subject to defects in their substance, brought about by pressure, volcanic action, and other causes, some of which are not yet known, that their quality often becomes much depreciated in consequence. This inferior variety of the iron-alumina garnet is called the "common" garnet, and has little lustre, being sometimes opaque. The perfect qualities, or almandine, as described above, are favourite stones with jewellers, who mount great quantities of them.

The second variety is the (B) lime-iron garnet, formula, $6CaO, 3SiO_2 + 2Fe_2O_3, 3SiO_2$. The chief of this class is the melanite, sometimes dull, yet often vitreous; it is mostly found in volcanic rocks, such as tuff; this variety is very popular with jewellers for mourning ornaments, for as it is a beautiful velvet-black in colour and quite opaque, it is pre-eminent for this purpose, being considerably less brittle than jet, though heavier. Another variety is the "topazolite," both yellow and green. The "aplome" is greenish-yellow, yellowish-green, brown, and usually opaque. A further form of lime-iron garnet is the "pyreneite," first found in the Pyrenees Mountains, hence its name.

The (C) lime-chrome garnets—$6CaO, 3SiO_2 + 2Cr_2O_3, 3SiO_2$—the chief of which is "uwarowite." This is of a magnificent emerald green colour, translucent at edges

and of a vitreous lustre. When heated on the borax bead it gives an equally beautiful green, which is, however, rather more inclined to chrome than emerald. This is an extremely rare stone in fine colour, though cloudy and imperfect specimens are often met with, but seldom are large stones found without flaws and of the pure colour, which rivals that of the emerald in beauty.

The fourth variety (D) is the lime-alumina garnet, its formula being—$6CaO$, $3SiO_2 + 2Al_2O_3$, $3SiO_2$. Like the others, it has a number of sub-varieties, the chief being the "cinnamon stone," which is one of great beauty and value when perfect. This stone is almost always transparent when pure, which property is usually taken as one of the tests of its value, for the slightest admixture or presence of other substances cloud it, probably to opacity, in accordance with the quantity of impurity existent. This variety is composed of the oxides of aluminium and silicon with lime. In colour it ranges from a beautiful yellowish-orange deepening towards the red to a pure and beautiful red.

"Romanzovite" is another beautiful variety, the colour of which ranges through browns to black. Another important variety is the "succinite," which gets up well and is a favourite with jewellers because of its beautiful, amber-like colour, without possessing any of the drawbacks of amber.

(E) The magnesia-alumina garnet — $6MgO, 3SiO_2 + 2Al_2O_3$, $3SiO_2$—is somewhat rare, the most frequently found being of a strong crimson colour and transparent. This variety is called "pyrope," the deeper and richer tints being designated "carbuncle," from the Latin *car-*

bunculus, a little coal, because when this beautiful variety of the "noble" garnet is held up between the eyes and the sun, it is no longer a deep, blood-red, but has exactly the appearance of a small piece of live or glowing coal, the scarlet portion of its colour-mixture being particularly evident. The ancient Greeks called it anthrax, which name is sometimes used in medicine to-day with reference to the severe boil-like inflammation which, from its burning and redness, is called a carbuncle, though it is more usual to apply the word "anthrax" to the malignant cattle-disease which is occasionally passed on to man by means of wool, hair, blood-clots, etc., etc., and almost always ends fatally. A great deal of mystery and superstition has always existed in connexion with this stone—the invisibility of the bearer of the egg-carbuncle laid by a goldfinch, for instance.

(F) The manganese-alumina garnet—$6MnO$, $3SiO_2$ + $2Al_2O_3$, $3SiO_2$—is usually found in a crystalline or granular form, and mostly in granite and in the interstices of the plates, or laminæ, of rocks called schist. One variety of this, which is a deep hyacinth in colour, though often of a brown-tinted red, is called "spessartine," or "spessartite," from the district in which it is chiefly found, though its distribution is a fairly wide one.

The Lapis-Lazuli.

The lapis-lazuli, sometimes called "azure stone," is almost always blue, though often containing streaks of white and gold colour, the latter of which are due to the presence of minute specks or veins of iron pyrites, the former and colourless streaks being due to free lime,

calcite, and other substances which have become more or less blended with the blue colour of the stone. It has a vitreous lustre, crystallises in the 1st, or cubic system, and is a complex substance, varying considerably in its ingredients in accordance with the locality in which it is found, its matrix, and the general geological formation of the surrounding substances, which may, by the penetration of moisture, be brought to bear upon the stone, thus influencing to a great extent its chemical composition. So that we find the stone composed of about a quarter of its substance of alumina, or oxide of aluminium, silica to the extent of almost half, the remainder being lime, soda, sulphur, and occasionally traces of copper and iron. It is mostly found in granite and certain crystalline limestone rocks, in fairly large masses. It is of great antiquity, figuring extensively in ancient Egyptian history, both in its form as a stone and ground up into a pigment for the decoration of sacred and royal vessels and appointments. When so ground, it forms the stable and magnificent colour, *genuine* ultramarine, which is the finest and purest blue on the artist's palette, but owing to its extremely high price its use is not in very great demand, especially as many excellent chemical substitutes of equal permanence are obtainable at little cost.

The Turquoise.

The turquoise is a pseudo-morph (see Chapter IV., "Cleavage.") In colour it is blue or greenish-blue, sometimes opaque, varying between that and feeble translucency, though it should be said that in all forms, even those considered opaque, a thin cutting of the stone

appears almost transparent, so that the usual classing of it among the opaque stones must be done with this reservation. In composition it contains about 20 per cent. of water, about a third of its substance being phosphoric acid, or phosphorus-pentoxide ; sometimes nearly half of it is alumina, with small quantities of iron in the form of variously coloured oxides, with oxide of manganese. The great proportion of water, which it seems to take up during formation, is mostly obtained in the cavities of weathered and moisture-decomposing rocks. Its average formula may be said to be $Al_2O_3P_2O_5 + 5H_2O$, and sometimes $Al_2O_3\,FeOP_2O_5 + 5H_2O$. It must therefore follow that when the stone is heated, this water will separate and be given off in steam, which is found to be the case. The water comes off rapidly, the colour of the stone altering meanwhile from its blue or blue-green to brown. If the heat is continued sufficiently long, this brown will deepen to black, while the flame is turned green. This is one of the tests for turquoise, but as the stone is destroyed in the process, the experiment should be made on a splinter from it.

This stone is of very ancient origin, and many old turquoise deposits, now empty, have been discovered in various places. History records a magnificent turquoise being offered in Russia for about £800 a few centuries ago, which is a very high price for these comparatively common stones.

Owing to the presence of phosphorus in bones, it is not uncommon to find, in certain caves which have been the resort of wild animals, or into which animals have fallen, that bones in time become subjected to the oozing

and moisture of their surroundings ; alumina, as well as the oxides of copper, manganese and iron, are often washed across and over these bones lying on the cave floor, so that in time, this silt acts on the substance of the bones, forming a variety of turquoise of exactly the same composition as that just described, and of the same colour. So that around the bones there eventually appears a beautiful turquoise casing ; the bone centre is also coloured like its casing, though not entirely losing its bony characteristics, so that it really forms a kind of ossified turquoise, surrounded by real turquoise, and this is called the " bone turquoise " or " odontolite."

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LONDON: PRINTED BY WILLIAM CLOWES AND SONS, LIMITED,
GREAT WINDMILL STREET, W., AND DUKE STREET, STAMFORD STREET, S.E.

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